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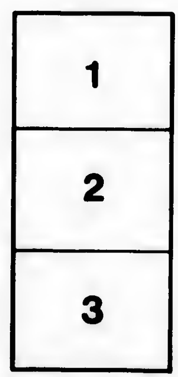
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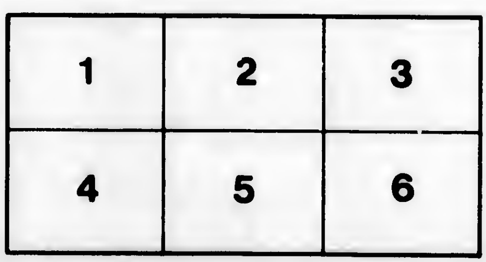
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GOLD:

ITS OCCURRENCE AND EXTRACTION.

Palmer districts.—An expedition in search of gold and other minerals in the Palmer districts, N. Queensland, was made by James V. Mulligan and party in April–September, 1875. The auriferous indications met with may be summarized as follows.

Byer's Creek.—All auriferous country, and little gullies and ravines have been worked.

St. George river.—On the upper waters, the formation passed over is mostly slate, but contains no indications of gold.

Hodgkinson river.—Between here and the Mitchell river is auriferous looking country, and the party found about 8 gr., and believed that more was to be had by searching. On another branch, colours were found, and a gold-field is suspected in the neighbourhood. Following another branch or feeder, some dishes of wash-dirt gave over 20 colours, yet not amounting to ½ gr. Mulligan believes there is a great extent of similar country, and that there are payable gullies, though they might be in little dabs. The formation is a foliated sandstone or slate, with hard bars running across, containing iron-pyrites in great abundance.

Mitchell river.—After crossing the Mitchell, an abundance of quartz, iron, and ironstones were met with. Innumerable colours were got in the dish, and specks sometimes as big as pins' heads, but no payable prospects, though there is a splendid wash. The position by observation was 16° 51′ 15″ S. Payable gold will be found not far from here, and this piece of country is highly auriferous. Farther on, colours and specks like pin-heads were met with everywhere, but no payable prospects.

Tate river.—On a creek running into the Tate, shotty colours of gold were found; and numerous colours in the Tate itself. Also colours of the finest description in Pint Pot Creek.

No payable deposits are reported throughout, but such doubtless exist at no great distance.

SOUTH AUSTRALIA.—Several gold-fields have been discovered and worked; but although gold is to be found in nearly every part of South Australia, none of the deposits of the precious metals has so far proved of great extent. The bed of the river Torrens has yielded a small quantity; but none of the finds has proved of an enduring character. The Echunga gold-fields, which were discovered in 1852, were the only ones of any value which had been worked up to that time; but they only gave employment to a comparatively small number of diggers. The same may be said of the Jupiter Creek diggings, in the same locality. The Barossa gold-fields, distant about 35 miles from Adelaide in a N.E. direction, were the next discovered; but these did not prove very rich as compared with the deposits in the sister colonies. Alluvial gold-digging was carried on for years at Barossa, and something has been done there in the way of mining. About 3 years ago, however, operations at the Lady Alice mine, which had been profitably worked for some years, and had yielded very rich quartz, were discontinued, capital not being forthcoming for carrying on deep-sinking. Gold has also been found in the Waukaringa district, in the North, where, for some years, several reefs were worked with fairly satisfactory results. An effort is now being made to obtain money for reviving operations in the district, and the prospects of success are promising. According to the Statistical Register for 1876, the gold exported to Victoria in that year was 2501 oz., value 9888*l.*; in 1875, the figures were 1802½ oz., value 7034*l.* The Chief Secretary at Adelaide kindly adds that he telegraphed to the Resident at Palmerston on the 10th December, 1881, and was informed in reply that up to that date inclusive, 132,000 oz., valued at 456,000*l.*, had been exported.

The following account of the several gold-fields is taken from Ulrich's report, dated 6th April, 1872, for a copy of which, among many other kindnesses, the author is indebted to that talented mining geologist.

Barossa.—This gold-field exhibits in its topographical and geological features a close resemblance to parts of Bendigo, Campbell's Creek, also to Dundley and other Victorian gold-fields, where the protective covering of basaltic lava is absent. Its principal gold-deposit is probably of Older Pliocene age, and consists of rounded quartz pebble and boulder drift, enclosing larger and smaller layer-like patches of ferruginous quartz conglomerate. At the head of an extensive valley, Spike's Gully, a real main lead is formed by a number of branch leads coming to a junction; and this main lead, in its course down the valley, is cut up by alluvial gullies into a number of hills of greater or less extent, and showing a depth of drift varying in thickness from 20 to nearly 100 ft. Both the older drift and the alluvial drift of the gullies are auriferous; but regarding the latter, several circumstances prove that the gold it contains was mainly derived from denuded portions of the former. Foremost amongst these may be mentioned the generally much water-worn character of the gold, and that the branch gullies are only auriferous where they pass between older drift hills. Higher up, beyond the latter, they cease to be so (a similar case as at the White Hills of Campbell's Creek, near Castlemaine). The richness of the main, or Spike's Gully, is due partly to the branch gullies having carried gold into it, partly to its intersecting the old lead in many places itself.

At the lower part of the diggings, private property stops the advance of the miner; but it seems quite certain that both the older and alluvial drifts continue to carry payable gold, and from the apparent strong dip of the older lead, it appears also probable that a so-called deep lead exists in the flats lower down the valley, i. e. the older drift may rest on the bottom of the valley, and be covered by alluvial drift, in which case there is a likelihood of the existence of two auriferous layers—that of the alluvial drift, resting on a false bottom, the top of the older drift; that of the latter on the true rock bottom. The branch leads at the head of Spike's Gully run over one of the highest ranges, in fact the watershed of the district, and are lost, i. e. washed away beyond the range by a strong creek, which thereby became auriferous, as proved by the alluvial workings, yielding water-worn gold down its course. Considering that they have once been creek beds, enclosed between ranges, but lie at present at a higher level than the ranges for some distance beyond, here is an instance of the enormous amount of denudation the country has suffered in bygone times. Ranges are worn down to below the beds of the creeks that traversed them, and the drainage of the country is quite altered, in fact partly turned in the opposite direction.

It is evidently quite impossible to determine the exact locality of the quartz reefs, whence the gold of the old leads was derived. So much is certain from the perfectly rounded character of the quartz pebbles and boulders, that the material must have travelled a considerable distance; and the occurrence of highly micaceous clays and occasional pebbles of metamorphic sandstone, in the heaps of drift round some of the shafts, indicates besides that it came from a district composed of metamorphic rocks, perhaps from part of the same belt of metamorphic ranges in which the Blumberg gold-field is situated; for at Barossa, the rocks show no, or but slight, traces of metamorphic action.

From the fact that some of the gold found in the alluvial drift is less water-worn than the rest, there is, no doubt, also a probability of auriferous quartz reefs existing within the area of the gold-field itself, and one large "blow" of a quartz reef cropping through the old drift deposits has been tunnelled into and prospected by shafts, but whether gold was found, Ulrich could not ascertain. In looking at the extent and nature of the workings in the old drift hills, it seems that a number of them are but partially worked, and therefore—as is done at similar places in Victoria—tunnelling into them, and sluicing the washing stuff of the banks left standing between the old claims, might prove a profitable undertaking, the contour of the country being very favourable for the construction of reservoirs at no great expense.

Blumberg.—The rocks comprising this field, as far as traversed, are both of eruptive and metamorphic character. They consist of mica-schist and hard micaceous quartzose sand and flagstones, here and there traversed by massive dykes, and showing protrusions of a very coarse-grained granite, which is characterized by containing only white mica in large plates, and to which no doubt the metamorphic character of the rocks is due.

Criterion reef.—This reef is supposed to traverse a lowish hill, on the top of which, a large crushing-plant is at present in course of erection. Owing to the manager's absence, and the shaft being inaccessible on account of water, Ulrich was not able to gain much information about the nature of this reef. At the place where it originally cropped out, at the western foot of the hill, close to a small creek, and was found very rich in coarse gold, is a trench-like excavation; but the bottom of it being covered with mullock, the reef could not be seen. According to the nature and direction of this cutting, the strike of the latter seems to be W. 25° to 30° N., and its dip N. 25° to 30° E., at a rather flat angle. The quartz lying near this place is good-looking, being somewhat seamy, and strongly impregnated with iron-pyrites and brown iron-ore. Empty cubical cavities, caused by the decomposition of the pyrites, impart to some fragments quite a cellular texture. The country consists of highly micaceous sandstones, alternating with mica-schist, and is decomposed, and easily brought near the surface, but becomes very hard and tough in depth; strike, N. 30° W.; dip, apparently E. 30° N. at 45° to 50°.

Beyond the excavation up-hill there is no outcrop of a reef observable at the surface; but at a distance of about 2 chains up the slope lies a vertical shaft in which, according to Williams (the former proprietor of the ground, and original discoverer of the rich outcrop), a strong quartz vein was struck at some depth down; but whether it was found auriferous he could not tell. A large and deep shaft, sunk in front of the machinery shed, lies considerably out of the line of strike and dip of the reef, as indicated by the first-mentioned excavation, and is therefore, perhaps, only intended for a water-shaft. There are, in different parts of the hill near the machinery, shallow holes and trenches in which strong quartz leaders are exposed, differing in strike from the supposed line of the reef. About their character, whether gold-bearing or not, Ulrich could not gain any information. On reviewing the results of his inspection, they are certainly unsatisfactory, regarding the character of this reef, and the prospects of the place generally; still, considering the large expenditure which the proprietors incur in the erection of the crushing-plant, previous to a proper opening of the reef and leaders, it must be concluded that they are thoroughly satisfied touching their gold-bearing character and capabilities, as exhibited in the workings executed.

The alluvial gully, running close past the rich outcrop, and crossing the supposed line of the reef, has not as yet been tested, though it has every prospect of being auriferous below that line.

German reef. — Having in Melbourne frequently heard credible accounts as to the richness of this reef, and actually seen splendid gold specimens obtained from it, Ulrich was not a little surprised to find it quite neglected, and a fine crushing-plant, erected close by, doomed to inactivity and slow decay.

The reef shows a well-defined outcrop for above 20 chains in length, running over a long, gently-sloping hill, across a gully, and up another hill, at a strike of N. 15° E., and dipping W. 15° N., in places steplike, steeper and flatter at angles varying from 25° to 50°. The rocks which it traverses strike N. 40° E., and dip W. 40° N. at 55°, and consist, as at the Criterion reef, of highly micaceous metamorphic sandstone, alternating with mica-schist.

With regard to the auriferous character of the reef, a man in charge of the place (who was employed as a miner during the whole period the reef was worked), gave Ulrich all the information embodied in the following description. Gold was found in the outcrop for a distance of at least 10 chains, and in two places extremely rich. At one of these places, low down the slope of the first long hill, the reef has been worked on the underlie to a depth of about 40 ft., and for above 100 ft. in length. It shows in the faces tolerably well-defined walls, and an alternating flatter and steeper dip. The thickness of the portion removed varied from 2 to 6 ft., and the quartz became rapidly poorer in depth—the average yield of that last raised having been 3 to 5 dwt. per ton. The second place where rich gold was found lies on the top of the hill, but the outcrop has here only partially been worked. There exists, however, a fine vertical shaft, which struck the reef at a depth of between 90 and 100 ft., but rather poor, and only about 6 in. thick, whilst its thickness at the top ranged from 2 to 5 ft. in places. The quartz all along the outcrop is rich in iron-pyrites, and some shows by its cellular texture and very ferruginous character, that much of this ore has been decomposed. The latter, becomes, however, still more abundant in depth, and the fine, seamy quartz raised from the large vertical shaft, on top of the hill, contains it perhaps at the rate of 25 to 30 per cent. In cases of such strong increase, in connection with a decrease of free gold in depth, it has generally been found in Victoria that the pyrites is payably and sometimes even richly auriferous. Matthew Barker, the late mining manager of the reef, evidently remembered this fact from his Victorian experience, for, by a simple contrivance, attached to the crushing-machine, he saved several tons of the ore, which are stacked in bags near the plant. Should an average sample of this have been assayed with the result at the rate of not less than 2 oz. per ton, its treatment, in the manner practised at Clunes and Bendigo, would no doubt be a payable undertaking, and might render the reef profitable to work. But, irrespective of this, on considering the fine development of the reef, the large extent of it as yet unworked, though proved auriferous, and that a fine crushing-plant is at hand, supplied with good gold-saving appliances and plenty of water at command, Ulrich cannot help thinking that another attempt at working it—with special attention being paid to the possible occurrence of the gold in shoots—would be advisable, and might be attended with better results than the first. For opening it at greater depth than hitherto reached, there would be required, however, another main shaft, lower down the hill towards the first workings, and farther off in the direction of its underlie, than the one existing on top of the hill.

The surface round the reefs, and the adjacent gullies have not, as yet, been worked, though they are in all probability payably auriferous.

Alluvial Deposits.—Of these, Ulrich inspected a small gully worked by several parties—one of the claims belonging to Hines, who kindly supplied Ulrich with all the information he asked concerning the occurrence of the gold. The alluvion of this gully is 3 to 5 ft. thick, and consists at the top of brown or brown and yellow mottled sandy clay, and beneath of 1 to 2 ft. of clayey angular quartz gravel, which rests on a very soft bottom, composed of mica-schist. Where it thins out on one of the bounding rises, the surface is found payably auriferous up to a spot covered with a number of loose quartz blocks; and as the gold obtained is throughout of a crystalline, rather spongy character—not the least water-worn—it must have been derived from a quartz reef lying in close vicinity; and this supposition is strengthened by the frequent occurrence of specimens, both of brown iron-ore and quartz, thickly impregnated with gold.

A quartz reef struck below the alluvial at 2 places by Hines, and which apparently strikes right for the spot where the gold was lost and the loose blocks of quartz appear on the surface, is therefore most likely the one which supplied the gold to this portion of the alluvial drift, and certainly deserves to be opened up.

From the fact, however, that the gully continues payably auriferous beyond this point, towards the top of the range, it must be concluded that the gold there occurring in it has been derived from one or several other quartz reefs lying in that direction. Considering that the stuff in its entire thickness pays well, though it has to be carried a distance of fully ½ mile to a puddling-machine erected at the river Torrens, and moreover that, according to the warden, Peterswald, a number of similar small gullies, all payable, have been opened over a belt of country of nearly 14 miles in length, Ulrich thinks sufficient evidence is afforded to consider the gold generally well distributed (most likely in the line of a zone of auriferous quartz reefs, including the German, Criterion, and other reefs discovered), and that there is every probability of its existence in payable quantities in the intervening gullies.

What in Victoria have generally proved to contain the richer alluvial deposits—the main gullies—to which the just-noticed small gullies form tributaries, have not been as yet tried, and present therefore a promising field to the prospector. As regards the older gold-deposits—rounded quartz, pebble drifts, and conglomerates—Ulrich found no traces of their existence in the part of the country traversed. They might possibly occur on the tops and slopes of the highest hills and ranges, and are not easily recognizable on account of the dense vegetation; but from observations made at Barossa and Echunga, he is more inclined to believe that they are absent; if once in existence, they have since been entirely removed by denudation. Notwithstanding, however, this defect, he considers from the features observed, that this gold-field, as far as regards alluvial drifts and quartz reefs, is a highly promising one, and only requires a rush of enterprising miners for its proper development.

In conclusion, Ulrich mentions that he saw in Stratford's collection of samples of alluvial gold from this field one that much resembles the so-called spider-leg gold, known from some of the northern gold-fields of Queensland; and as this kind of gold occurs there, not only in alluvial drift, but also in felspathic greenstone and elvan dykes, from which the drift-gold is derived, there is a strong probability that such is the case on this gold-field also, and prospectors ought therefore to keep a sharp look-out for and carefully examine any such dykes found.

Echunga. Old Echunga diggings.—Here obtain to a great extent the same geological features as observed at Barossa, i.e. a probably Older Pliocene drift-lead, composed of rounded quartz, pebble drift and conglomerate, occupying the tops and slopes of pretty high ranges. Payable and even rich water-worn gold was found in this deposit, and where it has been denuded along the slopes of the hills, and by gullies intersecting it, as, for instance, at the Chapel and Pedlar's hills—enclosing the Poorman's and Christmas leads—two deeper runs of drift separated by a high rise—by Felthouse's Flat and Chapman's Gully, and farther on the Bell's Point lead, by Long Gully—rich surface and alluvial drifts are the result. There is, however, this difference from Barossa, that a great part of the gold washed from these latter deposits (at Felthouse Flat and Chapman's Gully), is not water-worn like the rest, but hackly and crystalline—a circumstance which clearly indicates that, whilst the water-worn portion came from denuded older drift, the hackly one was derived from quartz in the immediate vicinity. Where the workings of Chapman's Gully terminate, at the boundary of private property, there is indeed a strong quartz reef crossing the gully at a strike of N. 25° E., which has been tried in several places, and in which gold is said to have been found, though not in payable quantity. The trials made are, however, neither very judicious nor extensive enough; and Ulrich believes, therefore, that another attempt at opening this reef, more especially at a deeper level, and where it crosses the gully, would be attended with a better result.

The quartz is throughout very good-looking, and impregnated with iron-pyrites at the surface. It is much to be deplored, regarding the development and prosperity of this field, that the further working of the alluvial deposits, both at Felthouse Flat and Chapman's Gully, is stopped by private property, the owner of which will not allow the miner to enter on any terms; for there cannot be any doubt that both flat and gully continue to carry payable if not rich gold in that direction. That, in Pedlar's Hill, the gold ceases at a hard sandstone bar, does not, as some miners suppose, arise from a throw or fault of the lead; but is simply explained by the fact that the sandstone bar forms the lateral boundary of the old river channel, the continuation of which longitudinally, beyond the hill, either side, has been completely denuded—the hill, in fact, is the result or a remnant of this denudation.

The so-called Long Gully crosses, as already noticed, part of the same old lead, which was found to contain several rich runs, called by special names, that named Bill's Point, having proved the richest; and from the fact that the gully is not payable above, and becomes rapidly poorer in its downward course below the old lead, and its gold being nearly throughout water-worn, it must be concluded that the latter came mainly, if not wholly, from the denuded part of that lead. In the continuation of the latter, on the opposite hillside, some payable claims have been worked; but farther on, where it deepens, it was found too poor to pay, and is, therefore, left untouched for a considerable distance down towards Jupiter Creek. Considering the short distance of the point where the workings terminate, from the rich runs just noticed, it seems not at all likely that a lasting impoverishment of the lead from that point onward is well established by the few holes scattered about, and another trial of it would therefore not only be an advisable, but also a promising undertaking.

In Long Gully are 2 fine reservoirs full of water, each of which lies close to a neglected crushing-machine, erected for the purpose of crushing the conglomerate, or "cement," as it is usually called, forming part of the older drift. Such conglomerates very rarely appear, according to Victorian experience, in long continuous layers; but occur as larger or smaller cake-like masses on the bottom, and more frequently higher up the drift deposit. Yet they are only richly or payably auriferous where they occupy the former position, or, in reality, represent the washing-stuff. The ill success of both the crushing enterprises named arose simply from the fact that either no heed was taken of this latter circumstance, or that it was unknown. All conglomerate was considered worth working; and as but little of the rich bottom conglomerate was left by the diggers in the worked-out lead, the higher-lying cakes next attacked proved quite unpayable.

Jupiter Creek.—One, perhaps the chief, part of the gold of this creek has likewise been derived from denuded older drifts, as indicated by the rich cement cakes and the rich surface patch, composed of rounded quartz pebble drift, worked on the hill slope on its left side (looking down stream), and which lead into the creek flat just at the point where the latter proved richest. The source of the other part of the gold of this rich spot lies, however, in the range on the right side, from which, straight opposite the surface patch, a small auriferous alluvial gully descends into it. For the gold found in this gully being thoroughly hackly or but very slightly water-worn, and auriferous quartz specimens frequent, it is quite certain that there exists one or perhaps several auriferous quartz reefs somewhere about the head of the gully. Some miners have already prospected the locality for this reef, but without success. Still the certainty of its existence should prompt to further search, until the discovery be accomplished.

From the circumstance that, at the upper margin of the rich surface and cement patch, both drift and cement are dipping into the hill, it seems that here is the commencement of a small "older drift lead," the gold of which was also probably derived from the same auriferous quartz reef that supplied the alluvial gully.

It appears very strange that this lead has not as yet been followed by tunnels farther into the hill, where it is bound to join the old main lead, trending down from Long Gully along the top and slope of the range. There can be no doubt that this part of the gold-field presents encouraging prospects to the enterprising miner.

At one side and near the top of the rich surface patch, exist the ruins of a crushing establishment, with a deep pump-shaft close by. This venture, Ulrich heard, was intended for working an adjoining ferruginous, slaty, sandstone reef, much traversed by quartz veins, from which the rich gold of the surface patch and creek flat was thought to have been derived.

Considering that, as above shown, the gold did undoubtedly come from denuded older drift, that the sandstone reef was found non-auriferous, and that there was besides not sufficient water for crushing, the want of success of this enterprise is easily explained.

Sterling reef.—This is, as far as Ulrich could learn, the only auriferous reef worked in the neighbourhood of the old Echunga diggings, though its position renders it very doubtful whether it furnished any gold to the auriferous drifts there occurring. It lies about 3 miles from the diggings, on top of a tolerably high range on the W. side of the Onkaparinga river, and runs between micaceous sandy slate and massive beds of coarse felspathic quartz grit, at a strike of N. 30° E., dipping apparently vertical, whilst slate and grit, though showing the same strike, dip E. 30° S. at 60° to 65°.

As regards its character, it is in reality not a genuine quartz reef, but conforms more to what are called mullock reefs in Victoria. One may compare it to a large fissure, in places 30 to 40 ft. wide, filled confusedly with larger and smaller masses of the wall-rocks—grit and slate—and the interstices between these masses occupied by mullock, enclosing irregular pockets and veins of quartz, through which (but more especially through the quartz) rather solid crystalline specks of gold are distributed. Iron-pyrites has not as yet been observed. The mullocky portions (irregular veins, as it were) cross the reef-mass in all directions (horizontally, vertically, and obliquely), and on this account, as each vein cannot be specially followed, the workings have to be carried on by quarrying the reef out *en masse*, and classifying the stuff afterwards,—a rather troublesome work, during which it cannot be prevented that a large amount of poor or non-auriferous matter becomes mixed with the quartzose mullock; hence the low yield of the latter of only 2 to 2½ dwt. per ton on the average.

The workings extend at present about 6 chains along the strike of the reef, the principal one being a wide quarry-like open cutting, several chains in length, and 10 to 14 ft. deep at the up-hill end; farther on, follows a large open pit, and beyond this, right on the top of the spur, are several shafts, in all of which the auriferous mullock has been struck.

Several small shallow gullies descending from the reef down the slope of the hill have been found payably auriferous, and there can be no doubt that this reef contributed largely by denudation to the gold found in the Onkaparinga river, not far off, and more especially at and below the point where its line of strike crosses the latter.

All considered, Ulrich believes it might profitably be worked on a larger scale than is at present the case, and that there is a chance of its becoming much better defined in depth. That this reef is the only auriferous one in the district is also very unlikely, and careful prospecting of the neighbourhood would therefore be an advisable and promising undertaking.

The auriferous mullock of the reef is crushed by a 5-head battery, erected at the foot of the range, close to the Onkaparinga river, which latter would furnish plenty of water for any number of stamps in addition.

The amalgamating appliances of this machine are very elaborate, but the blanket-strakes (the great advantage of which has been long and satisfactorily demonstrated in Victoria) are wanting; there is also too little water used for crushing, and the speed of the latter is too slow—hardly 60 strokes per minute. That the water used is insufficient in quantity is, on account of the softness and clayey nature of the stuff, especially detrimental, for it leads to an accumulation of the slimy tailings in the mercury-troughs and on the copper plates, in consequence of which the gold cannot properly come into contact with the mercury, and is liable to be carried off by the strong narrow currents of water originated. Besides this, the mercury itself is in danger of being splashed out of the troughs whenever the sludgey accumulations are being removed. With sufficient water, and a speed of about 80 stamper-strokes per minute, nearly double the present quantity of stuff might, perhaps, be crushed during the same time; whilst the addition of blanket-strakes to the amalgamating appliances would more satisfactorily ensure the saving of the fine gold, at present, no doubt, lost to a great extent.

Ulooloo.—This gold-field is of special interest in a geological point of view, on account of its position—some 25 miles N. of the Burra Burra mine—i. e. within a rock area forming part of the extensive N. mountain region, considered and proved favourable for copper-ore, but in which the existence of gold was altogether doubted.

The rocks of this field, throughout the part examined, consist of flaggy, grey, brown, and bluish slates, alternating with massive quartzite and gritty sandstones, all traversed by quartz veins,—a series which, lithologically, is not distinguishable from that met with several hundred miles farther N., and noticed as showing an auriferous aspect. The non-discovery of fossils both there and here precludes, unfortunately, the establishment of their true geological relations.

The field, as far as opened, exhibits shingly creek deposits, brought down since ages past from the bounding ranges, and which may accordingly be divided into recent and older ones.

The recent deposits are those shingly drift layers occupying the beds of the creeks, which beds have mostly been washed out several feet deep in the slate rocks; and as the surface of the latter is generally hard, very uneven, and much jointed and cleaved, the obtaining of the richer wash-dirt is very troublesome, as careful scraping and brushing out of the hollows and cavities—in fact, regular fossicking—has to be resorted to.

Regarding the older deposits, they form banks of 6 to above 20 ft. in thickness, composed of clay, sand, shingle, &c., between the main and branch creeks, and are, apparently, the richest in gold. The chief diggings extend for about 1 mile up a dry main branch of the Ulooloo Creek, running nearly N. and S. in the strike of the rocks —some parties working the creek bed, and others, and they form the greater number, operating in the adjoining banks of older drift by shafts and drives. There can hardly be a doubt, however, that other branches of the Ulooloo Creek and the latter itself are auriferous, and will soon be attacked. Touching the gold found, it is generally coarse and solid, frequently even nuggety in character, and resembles somewhat that of Daisy Hill, in Victoria.

A serious difficulty under which the miners labour is want of water, for the washing-stuff has to be carted a considerable distance to some water-holes in the Ulooloo Creek, and these, it is to be feared, will in a dry season soon give out. Some other water-holes lower down the creek might then, perhaps, be still available; but the, no doubt, much higher rate of cartage would greatly affect the earnings of the diggers. Judging from the character of the stuff, it appears very favourable for sluicing or working in the long-tom; and with plenty of water at command, a considerable amount of gold might be produced in a short time by attacking the older creek deposits *en masse;* for it seems from the arrangement of the drift, incident to its mode of deposition by floods and creek currents, that not only the bottom layer, but also intermediate higher layers, are very likely to contain gold—a point at present overlooked. As regards older hill deposits, i. e. rounded quartz-pebble drifts and conglomerates, no evidence of their existence is apparent, nor is there a likelihood of the occurrence of deep leads, except it might be at the point where the Ulooloo Creek passes out of the ranges into the E. plain; and whether the gold did exist there in large enough quantity to pay for the far more troublesome and expensive modes of working required, is doubtful, considering that its higher sources have hitherto not proved rich. The main hope for the permanency of this gold-field lies undoubtedly in the discovery of the quartz reefs from which the drift-gold has been derived, and these have to be searched for in the ranges bounding the main creek and its branches.

According to the but slightly water-worn character of the gold found at the present principal diggings, the reefs that there supplied the metal can indeed not lie far off, and the intended prospecting by some enterprising miners of several well-defined reefs higher up the creek has good chance of proving successful, more especially as auriferous quartz specimens have been found in close neighbourhood to these reefs.

The country round the diggings is generally well wooded, and the miner can therefore easily provide the necessary timber for rendering his shafts and drives safe for working.

The Northern Territory.—Taking the overland telegraph as a base line, the gold-fields at present known extend from the Stapleton to the Driffield, a distance of more than 100 miles in a S.S.E. direction. The main road from Port Darwin to the reefs runs pretty close to the telegraph-line, and the gold-workings, as a rule, are a few miles to the E. or W. of this road. The width of auriferous country has recently been proved by prospecting parties to be much greater than was formerly supposed, Chinaman's Rush being over 20 miles from the telegraph-line.

From this, it will be seen that gold is distributed over a very large area, and wherever slate and quartz are met with, the precious metal is usually to be found in minute grains; but the rich patches which lure the digger from one country to another are deposited in a very puzzling and uncertain manner. There are no long leads of auriferous drift—most of the alluvial gold being found in short gullies and ravines—so that a great deal of prospecting has to be done before payable ground is usually reached. Occasionally rich pockets are met with, which suddenly reward the miner for months of unremunerative toil; but the prizes are not scattered with a too lavish hand, and gold-digging in the Territory, as nearly everywhere else, becomes a matter of working for something like a living. In the rainy season, when water is abundant, the Chinese do a large amount of "surfacing," often washing fine gold out of the earth-bound roots of the grass. During the dry months, many of the more energetic miners stack their wash-dirt, and sluice it when the heavy rains of the following wet season begin to fall.

Quartz reefs and leaders are numerous in the following districts:—Stapleton Bridge Creek, Howley, John Bull, Britannia, Fountain Head, Yam Creek, Chinaman's Rush, Extended Union, Union Lady Alice, Pine Creek, Driffield, &c. Some of these may be traced for miles, and many yield payable percentages of gold; but none has been tested below 200 ft., and only a few have gone down more than half that depth. The proper development of the reefs depends, as with all other industries, on railway communication. When cheap and easy conveyance reduces the cost of carriage and of food, tens of thousands of tons of stone, bearing ½ to ¾ oz. of gold to the ton, will be manipulated by powerful machinery, and made to pay handsomely.

Rich leaders, carrying 10 to 50 oz. of gold to the ton, are occasionally met with, and return large yields of treasure; but they almost invariably die out, and are, therefore, not to be regarded as possessing the permanent value of quartz lodes. The average yield of all the quartz which has been crushed has been about 1¼ oz. of gold from the ton of stone.

Some of the hills are interlaced with leaders and veins that are too thin to work upon separately; but the day will come when great faces will be opened out, the workmen taking all before them, as at the Black Hill at Ballarat, and the whole mass—good, bad, and indifferent—passed through the crushing-mill with satisfactory results.

Quartz-reefing is now carried on by small parties of working miners, so that there is but little chance of any deep shafts being sunk in order to determine whether the lodes go down and carry gold. It has been suggested by the Chief Warden, on more than one occasion, that the Government should follow the example of other colonies, and offer a substantial reward for the discovery of a payable reef not less than 18 in. wide, at a depth of 300 ft. Should such a thing be found, and further researches demonstrate that the reefs, like those in Victoria, carry gold down to a great depth, new life and vigour would be infused into the mining community, and money would be easily obtained to work the claims on a large and systematic scale.

The mining regulations are exceedingly liberal, and the only permit required is a miner's right, which costs 10*s.* per annum. One man can take up a block of ground, for alluvial digging, 25 yd. by 25 yd.; and two men can work on a claim 50 yd. by 30 yd. Miners who go out prospecting and find a new gold-field are entitled to take up very large areas by virtue of being the first discoverers.

With regard to reefing, the regulations are still more liberal, two men being allowed to hold 200 yd. on the length of the reef by a width of 250 yd. Leases of ground may be obtained for quartz claims and land on which there is deep sinking. These leases give the holders complete security of tenure for 21 years, at a rental of 10*s.* per acre per annum. Dams and machinery sites may occupy 10 acres, and ¼ acre is allowed for a residence site. The Warden's camp is about the centre of the present known gold-fields.

From the report of the Surveyor-general, written at Port Darwin in September 1869, the credit of being the first discoverer of gold in the Northern Territory is given to Litchfield. R. C. Burton subsequently searched for gold under the direction of Goyder, and found fair prospects.

In 1880, Price reported that there were about 150 Europeans and 1500 Chinese on the reefs engaged in mining; and the export of gold, as far as could be ascertained, was fully 20,000 oz. per year. Nearly half of this finds its way to Hong Kong in private hands, the Chinese being very fond of remitting small parcels by their friends for the support of their families. Several Europeans who stuck to the alluvial have gone away well satisfied with their takings; and a number of Chinese have returned to their country with a sufficient capital to set them up in business. A new rush has taken place lately on the Margaret river, and there about 400 Chinese are doing well—some very well; and one reef on the place, called the Twelve-mile Rush, is turning out well, so well, indeed, that the owners have called it Pay-me-well reef, and with good cause, if they get future crushings like their first.

In 1881, the arrival of 3000 more Chinese was expected. The rule is that the Chinese population always goes on increasing during the wet season, from November to March, and decreasing during the dry season, from April to October; but the decrease is small in comparison to the increase, so each year increases the number of Chinese on the whole. The population was given as: Chinese, 3690; Europeans, 660; Malays, 30. The revenue from miners' rights reached 676*l.* The amount of gold exported since July 1, 1880, was 28,471½ oz. The discovery of a new gold-field at Bridge Creek came just at the right time, as the question previously was how to tide over the dry season. The last wet season on the gold-fields was the worst ever known, as water was scarce all the season, except during the months of February and March, consequently it was a difficult problem how to get through the 6 dry months; but at Bridge Creek, which is 24 miles from Yam Creek, there was sufficient water to start with. This field has been very successful, although there have not been such heavy finds as at the Margaret; still, as a gold-field, it is much superior, being of greater extent, and this time the Europeans are securing their fair share of gold. Until next wet season, when water will be plentiful, it cannot be fully developed, nor the full extent ascertained; but in the meantime it is supporting a population of over 100 Europeans and about 1500 Chinese, and there is a fair prospect of its being a permanent gold-field for some time. Another new gold-field, 45 miles E. of Pine Creek, and known as Sanders' Rush, has been deserted for want of water; but, from various reports, it will be a very valuable field in the wet season, as, during the short time the water lasted after its discovery, a large quantity of gold was raised. These two new discoveries will probably bring a large increase to the Chinese population next wet season. A fair amount of gold was being raised from the other reefs, and one very rich patch at the Margaret yielded 520 oz. pounded in a pestle and mortar from less than a ton of quartz; and in another reef close by 2 tons of quartz yielded 216 oz. The payment of the 500*l.* bonus to D. B. Tennant for his discovery of the Margaret had given very general satisfaction.

TASMANIA.—Gold-mining was more actively pursued in 1878 than ever before. The average number of persons employed in this industry was 1050, the next highest number having been 530 in 1872. The approximate value of mining plant was: in 1878, 46,000*l.*; in 1872, 19,500*l.* From alluvial operations, 11,462 oz. of gold, valued at 45,750*l.*, were produced, against 4020 oz., valued at 15,768*l.*, in 1871, the highest yield previously. The number of tons of quartz crushed in 1878 was 15,805, yielding 13,787 oz. of gold, valued at 54,250*l.*; the average value per oz. was 3*l.* 18*s.* 8*d.*, and the average yield per ton of quartz, 17 dwt. 12 gr. The largest quantity of stone crushed previously in one year was 8516 tons in 1877; the largest yield, 11,007 oz., in 1876; and the highest average per ton, 1 oz. 8 dwt. 3 gr., in 1876. The total quantity of gold produced in 1878, so far as it could be ascertained, was 25,249 oz., valued at 100,000*l.*

The Commissioner of Gold-fields, in a report (dated 4th September), after referring to the impossibility of ascertaining the exact amount of alluvial gold obtained, and stating that the quantity returned was within the actual yield, thus proceeds:—Since the beginning of this year (1879), two important discoveries of gold in alluvial deposit have been made; one, near Mount Arthur, named Lisle, and the other at the Pieman river, near the W. coast. At Lisle, mining operations are being carried on in a most active manner, and there cannot be less than 1500 men employed. The gold is in shallow deposit, easily obtained, and is of a good quality. It is roughly estimated that not less than 20,000 oz. have already been procured. As usual, the miners seldom sell more in the colony than provides funds to pay current expenses, and many send large parcels by private hand to Melbourne, where it realizes a higher price. Gold transmitted in this manner is seldom or never entered at the Customs, and the Customs returns of gold exported are therefore no indication whatever of the actual produce of the colony in that metal. On the W. coast a limited number of miners are engaged, principally on the river Pieman, and several hundred oz. of gold of a very superior quality have been procured; but the almost inaccessible nature of the place, the extraordinarily rough and scrubby country, and the severely wet climate, have prevented any extensive prospecting during the winter months.

Several batteries have been erected at Beaconsfield to crush a species of auriferous conglomerate, locally termed "cement," with every prospect of success. No change worthy of notice has taken place in the condition of the mining industry on any of the other gold-fields since the close of 1878. The number of miners' rights issued since 1st of January, 1879, is 2300, and there are 2000 men engaged in gold-mining pursuits throughout the colony. The yield of gold from quartz since 1st January, 1879, was 14,500 oz., valued at about 58,000*l.*

Gold was obtained from Fingal in considerable quantities by odd stragglers with very rude machinery for years. A reef was worked by the Fingal Quartz Mining Co., which produced 20, 30, and 40 oz. per week; but on erecting new machinery the affair failed.

West Tamar district.—The geology of the West Tamar district of Tasmania was described by Norman Taylor, in 1878. Gold is said to have been found in the Middle Arm Creek. The only reefs known to be auriferous are those at Brandy Creek, but at the time of Taylor's visit the only reef yielding good returns was the celebrated "Tasmania." Other reefs struck good payable-looking stone, but had to wait the advent of a long-promised crushing company.

An Older Pliocene Tertiary drift, derived from the denudation of the Silurian rocks and their contained reefs, covers the entire area of the higher portions of the low country between the two arms, almost completely obscuring the underlying rocks. It also caps the Silurian and serpentine hills up to elevations of nearly 300 ft. above sea-level, between the Cabbage-tree range and Anderson's rivulet. It is very widely spread; but Taylor has little doubt but that leads would be found, if looked for, in some portions of it. The Italian's and Scotchman's Co. tunnelled into it on a head of Brandy Creek, W. of the Cabbage-tree range, and struck a lead with good prospects; but were driven out by water. "Made hills" occur along the valleys of the Yorktown and other creeks running up into the Silurian and Metamorphic ranges.

On the E. side of the Brandy Creek or Cabbage-tree range occur some small leads, consisting of a reef-wash from the Tasmania reef, which probably belongs to the Older Middle Pliocene period. Brown's party were on good gold at a depth of 60 ft.; while only about 1½ chains to the E. the Grand Junction Co. were down 118 ft. without bottom, showing the existence of a ledge between the two, with a very steep vertical fall.

In conclusion, Taylor briefly mentions one or two other occurrences in connection with the reefs of Brandy Creek. Victorian reefs in general run in, or nearly so, the strike of the country; but here they make an angle of 30° to 40° with the strike, or nearly E. and W. The often-occurring carbonaceous or black schists forming the casings in many Victorian reefs are here represented by a brown, sometimes hard and siliceous, and at other times earthy-looking, light and friable sandstone, containing distinct plant-impressions, in the softer rock sometimes converted into coal. This occurrence has not been hitherto noticed, and is of great interest. This bed is said to form the hanging-wall in connection with the "Cabbage-tree" conglomerate of the "Tasmania" reef, and Taylor obtained specimens from their top shaft. The same rock also occurs in the shaft of the Providence Co. on the top of the range. In the Grand Junction Co.'s shaft, on the E. side of the range, it also occurs as boulders in the drift, and contains quartz pebbles, having no doubt been washed down from the reef in Middle Pliocene times. It contains gold in itself, and was being saved for crushing. Is it possible that these carbonaceous selvages to reefs have had any influence on or been the cause of the formation and segregation of gold in the reefs? Although much has been done by Professor Cosmo Newbery towards a solution of this puzzle, a great deal yet remains to be accomplished before an answer can be given to this important question.

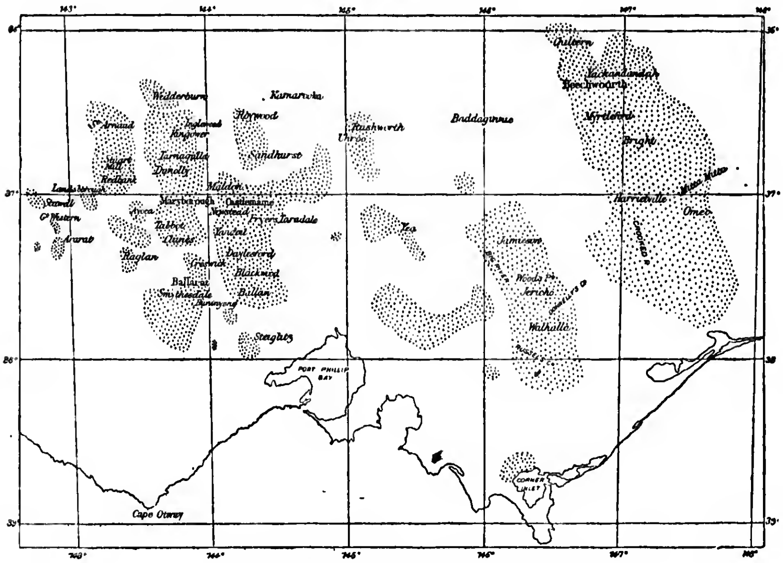
TIMOR.—According to Moor (1837), gold is found in several of the rivers of Timor, both in lumps and dust, some pieces weighing 2 oz.

Two of the most productive rivers rise in the centre of the island, and one falls into the northern, the other into the southern, sea. From a superstitious motive, the natives have an objection to any person taking the gold from these rivers, and except in very rare instances, do not ever touch it themselves. On those occasions, they do not presume to remove it until they have sacrificed a human being to the deity of the river, and then take only a very small quantity, never using it in traffic.

This is corroborated by Van Hogendorp, in his 'Description de Timor' ('Annales des Voyages,' vi. 280).

VICTORIA.—The following tables representing the development and condition of the gold-mining industry of this important colony are condensed from the voluminous report of its mineral statistics for 1879.

FIG. 22.



SKETCH-MAP OF VICTORIA GOLD-FIELDS.

Estimates of gold raised in Victoria during 6 years:—

	1874.	1875.	1876.	1877.	1878.	1879.
	oz. dwt.	oz. dwt. gr.	oz. dwt. gr.	oz. dwt. gr.	oz. dwt. gr.	oz. dwt. gr.
Exported, according to Customs Returns.	904,154 0	709,934 18 0	506,345 6 0	508,693 2 0	346,259 10 0	214,197 16 0
Received at the Melbourne Mint.	251,817 19	385,852 3 0	427,878 16 0	290,919 17 0	422,609 14 0	493,062 4 0
Raised, according to estimates of Mining Registrars.	1,097,644 0	1,068,418 0 0	963,760 0 0	809,653 4 16	758,040 15 19	758,947 5 21
Purchased, according to returns of banks.	1,105,115 0	1,077,276 5 5	949,468 12 17	790,147 8 10	772,302 15 20	736,253 7 11

The estimated yield of gold for 1879 is 906 oz. 10 dwt. more than the quantity obtained during 1878.

Estimated yields of gold from alluvial and quartz mines, since the year 1867:—

Year.	Alluvial.	Quartz.	Year.	Alluvial.	Quartz.
	oz.	oz.		oz.	oz.
1868 ..	1,087,502	597,416	1874 ..	433,283	664,360
1869 ..	934,082	610,674	1875 ..	426,611	641,806
1870 ..	718,729	585,575	1876 ..	357,901	605,859
1871 ..	698,190	670,752	1877 ..	.89,754	519,899
1872 ..	639,551	691,826	1878 ..	264,453	493,587
1873 ..	504,250	666,147	1879 ..	293,310	465,637

For the first time during 11 years the estimated yield of gold from alluvial mines shows an increase on that of the preceding year, due principally to a better water-supply for sluicing operations, and to the opening up of deep mining ground near Beaufort; but owing to the exhaustion of the auriferous drifts in the older workings of the gold-fields, it is hardly to be expected that yields from this class of mining will show any lasting improvement. There is still a slight falling off in the yields from quartz mines. The year 1879 shows no alteration in that respect from those that preceded it back to the year 1871, except that the diminished yields of 1879 and of 1878 are comparatively small. It is, however, to quartz mining that we have to look hopefully for future progress, and it is confidently anticipated that the recent discoveries of extensive and highly auriferous quartz veins at Ballarat, in close contiguity to the deep alluvial leads so long and profitably wrought on that gold-field, together with a great improvement in the prospects of vein mining at Maldon and other places, will cause an increase in the yields from this class of mining.

Yields of gold from parcels of quartz in the 6 years 1874–79:—

Year.	Crushed or treated.		Produce.			Average per ton.		
	tons	cwt.	oz.	dwt.	gr.	oz.	dwt.	gr.
1874 ..	967,069	9	573,220	17	5	0	11	20·51
1875 ..	949,468	12	565,561	10	10	0	11	21·92
1876 ..	1,011,808	4	534,328	6	19	0	10	13·48
1877 ..	965,573	15	453,372	19	9	0	9	9·38
1878 ..	874,717	6	417,306	1	16	0	9	12·99
1879 ..	849,324	16	372,946	0	22	0	8	18·77

Quantities of quartz tailings, mullock, &c., crushed and treated, and results obtained therefrom, during the 6 years 1874–79:—

Year.	Quartz Tailings, Mullock, &c., crushed.		Produce.			Average per ton.		
	tons	cwt.	oz.	dwt.	gr.	oz.	dwt.	gr.
1874 ..	69,439	0	6,866	11	10	0	1	23·46
1875 ..	31,299	0	4,432	15	23	0	2	19·98
1876 ..	34,628	7	3,281	10	22	0	1	21·49
1877 ..	28,435	0	2,938	9	5	0	2	1·60
1878 ..	38,281	14	3,502	13	12	0	1	19·92
1879 ..	37,301	15	3,028	0	21	0	1	14·96

Quantities of pyrites, blanketings, &c., treated during the 6 years 1874–79, and gold obtained :—

Year.	Pyrites and Blanketings treated.		Produce.			Average per ton.		
	tons	cwt.	oz.	dwt.	gr.	oz.	dwt.	gr.
1874 ..	6,725	15	18,941	14	13	2	16	7·82
1875 ..	7,499	5	18,565	18	2	2	9	12·34
1876 ..	7,057	3	17,538	19	21	2	9	16·93
1877 ..	7,359	6	13,645	3	5	1	16	21·65
1878 ..	5,375	0	13,589	14	23	2	10	13·59
1879 ..	5,304	3	13,014	11	8	2	9	1·75

During the 11 years 1869–79, 58,040 tons 6 cwt. of pyrites were operated on, and a total yield of 146,905 oz. 8 dwt. 1 gr. of gold obtained, equal to an average of 2 oz. 10 dwt. 14·92 gr. per ton.

Quantities of vein-quartz crushed, and average yield of gold per ton, during the 6 years 1874–79, in the several districts :—

District.	1874.					1875.					1876.				
	Quartz crushed.		Average Yield of Gold per ton.			Quartz crushed.		Average Yield of Gold per ton.			Quartz crushed.		Average Yield of Gold per ton.		
	tons	cwt.	oz.	dwt.	gr.	tons	cwt	oz.	dwt.	gr.	tons	cwt.	oz.	dwt.	gr.
Ararat	63,757	0	0	18	9·80	75,467	10	0	17	23·16	88,729	0	0	16	22·47
Ballarat ..	276,409	16	0	7	15·88	283,668	12	0	8	17·60	315,407	6	0	6	14·46
Beechworth	73,125	15	0	10	5·26	64,042	4	0	11	1·93	65,638	12	0	11	6·61
Castlemaine	156,146	10	0	9	16·98	117,504	10	0	8	4·09	111,716	10	0	7	14·45
Gippsland ..	42,234	8	1	3	12·79	43,426	16	1	4	7·94	40,784	6	1	3	12·58
Maryborough	31,903	0	0	9	10·77	33,671	0	0	10	13·48	32,605	0	0	8	18·66
Sandhurst ..	323,493	0	0	14	6·35	331,688	0	0	13	6·09	356,927	10	0	11	22·86

District.	1877.					1878.					1879.				
Ararat	77,798	13	0	18	4·04	74,221	14	0	14	8·67	76,323	9	0	11	17·73
Ballarat ..	350,761	0	0	6	20·69	337,797	0	0	6	16·97	346,540	5	0	6	18·44
Beechworth	64,471	12	0	10	23·41	54,764	2	0	10	21·94	55,092	16	0	10	11·04
Castlemaine	94,463	0	0	6	13·90	75,397	0	0	6	1·91	75,692	0	0	5	18·45
Gippsland ..	35,517	0	1	1	12·24	35,518	0	1	0	21·69	26,991	12	1	2	18·66
Maryborough	40,409	0	0	12	6·02	38,261	0	0	17	10·38	36,603	14	0	11	22·67
Sandhurst ..	302,153	10	0	8	19·20	258,758	10	0	9	20·41	232,081	0	0	9	8·09

It will be observed that for 1879, the Gippsland district still holds the first place in regard to high average yields of gold, but the number of tons crushed is small as compared with the quantity treated in other districts.

The continuous decrease in the number of alluvial miners has ceased. The number employed in 1879 was 265 more than in the year 1878 ; the number of men engaged in quartz mining since the same year has increased 652. The increase in the number of both classes of miners, comparing the return for 1879 with that for 1878, is 917. The number of Chinese engaged in mining operations on 31st of December, 1879, was 9110. There is a decrease of 528 in the return for the past as compared with that of the preceding year. Dividing the value of the gold exported and received into the mint amongst the mean number of miners employed in the year 1879, the average per man is *76l.* 1*s.* 2¼*d.* The averages for 6 years are shown in the following statement:—

Year.	Alluvial Miners. — Earnings per man per annum.			Quartz Miners. — Earnings per man per annum.			Average Earnings per man per annum.		
	£	s.	d.	£	s.	d.	£	s.	d.
1874	58	9	2¼	183	0	9	99	8	3·07
1875	63	5	5	182	17	8	104	4	4·02
1876	51	10	7	160	17	9¾	89	19	6·84
1877	47	8	0¼	139	12	0¼	82	6	1·69
1878	47	3	6¾	138	7	7¼	82	12	11·38
1879	48	10	1½	118	8	7	76	1	2·32

Number of quartz reefs proved to be auriferous, and the total extent of auriferous alluvial and quartz ground worked upon, in the several mining districts, in 1879:—

Mining Districts.	Number of Quartz Reefs proved to be auriferous.	Square miles of Auriferous Alluvial and Quartz Ground worked upon.
Ararat	80	87½
Ballarat	347	159½
Beechworth	865	340½
Castlemaine	404	164
Gippsland	501	209½
Maryborough	613	127
Sandhurst	772	146
Totals	3,582	1,234

NOTE.—The number of quartz reefs cannot be strictly correct, as parts of the same reef, in some localities, are held to be distinct reefs, and named accordingly. As the reefs are further explored, it is found, too, that what were supposed to be separate reefs are not really distinct. The extent of auriferous ground is here put down from estimates made by the Mining Surveyors and Registrars, not from actual surveys; and in a few instances the estimates of the present Surveyors and Registrars differ from those made by their predecessors. The figures vary from year to year; and as the shallow alluvions of the older gold-fields are abandoned by the miners, they are taken up and occupied under the provisions of the Land Act, by agriculturists and gardeners; consequently ground which one year was included in the estimated area of gold-workings is excluded in another.

Gold obtained from quartz veins and alluvial workings during the year 1879:—

	oz.	dwt.
From quartz veins	433,925	10
From alluvial workings	273,334	10
Total gold exported and minted	707,260	0

NOTE.—The above figures are but rough approximations. The Mining Surveyors and Registrars can furnish only estimates based on information afforded by the banks and gold-buyers, and on their own knowledge of the character of the workings in their districts. The check on the returns—and not a sufficient one—is that afforded by the returns of quartz and quartz tailings crushed, pyrites operated on, and wash-dirt and cement treated, which, however, cannot and do not comprise information respecting all the stuff put through the mills.

AVERAGE YIELD OF GOLD FROM PARCELS OF QUARTZ CRUSHED IN 1879 :—

Mining districts.	Tons crushed.		Total produce.			Average yield per ton.		
	tons	cwt.	oz.	dwt.	gr.	oz.	dwt.	gr.
Ararat	76,323	9	44,798	10	1	0	11	17·73
Ballarat	346,540	5	116,767	17	4	0	6	18·44
Beechworth	55,092	16	28,803	15	8	0	10	11·04
Castlemaine	75,692	0	21,833	3	6	0	5	18·45
Gippsland	26,991	12	30,531	16	15	1	2	18·66
Maryborough	36,603	14	21,861	7	8	0	11	22·67
Sandhurst	232,081	0	108,349	11	4	0	9	8·09
Totals	849,324	16	372,946	0	22	0	8	18·77

NOTE.—The above table does not show the total quantity of quartz crushed in the several localities, but only the yield of certain "crushings," respecting which the Mining Surveyors and Registrars have been able to obtain information. Owing to the circumstance that many of the machine-owners are unable to give, or are precluded from giving, information, it is impossible to give complete returns from every district.

Since the first publication of the statistics, information has been obtained concerning 16,092,530 tons 19 cwt. which have been crushed, and yielded 8,791,155 oz. 5 dwt. 4 gr. of gold, being an average of 10 dwt. 22·21 gr. per ton.

AVERAGE YIELD OF GOLD FROM PARCELS OF QUARTZ TAILINGS, MULLOCK, &c., CRUSHED IN 1879 :—

Mining districts.	Tons crushed.		Total produce.			Average yield per ton.		
	tons	cwt.	oz.	dwt.	gr.	oz.	dwt.	gr.
Ararat	1,100	0	91	12	18	0	1	15·98
Ballarat	15,291	0	1,064	19	9	0	1	9·43
Beechworth	1,963	0	299	17	0	0	3	1·32
Castlemaine	13,002	0	772	13	0	0	1	4·52
Gippsland	637	0	163	19	0	0	5	3·54
Maryborough	3,290	15	377	10	18	0	2	7·06
Sandhurst	2,018	0	257	9	0	0	2	13·23
Totals	37,301	15	3,028	0	21	0	1	14·96

NOTE.—From 1864 to 1879, inclusive, 1,832,977 tons 16 cwt. of quartz tailings, &c., were crushed, and yielded 316,300 oz. 14 dwt. 13 gr. of gold, being an average of 3 dwt. 10·82 gr. per ton.

AVERAGE YIELD OF GOLD FROM PARCELS OF WASH-DIRT PUDDLED AND SLUICED IN 1879 :—

Mining districts.	Tons puddled or sluiced.		Total produce.			Average yield per ton.	
	tons	cwt.	oz.	dwt.	gr.	dwt.	gr.
Ararat	37,644	0	6,262	5	9	3	7·85
Ballarat	49,893	0	4,873	4	3	1	22·88
Beechworth	152,229	0	9,748	9	0	1	6·73
Castlemaine	321,007	10	20,389	17	4	1	2·75
Gippsland	..		..			..	
Maryborough	53,767	0	11,017	17	18	4	2·36
Sandhurst	..		..			..	
Totals	614,540	10	52,291	13	10	1	16·84

NOTE.—The above table does not show the total quantity of wash-dirt puddled or sluiced in the several localities, but only the yield of certain "washings" respecting which the Mining Surveyors and Registrars have been able to obtain information.

The collection of the statistical information relating to the yield of gold from wash-dirt was commenced during the quarter ending 30th June, 1872, from which period to 1879, inclusive, 6,622,831 tons 9 cwt. of wash-dirt were puddled and sluiced, and yielded 404,853 oz. 6 dwt. 15 gr. of gold, being an average of 1 dwt. 5·34 gr. per ton.

AVERAGE YIELD OF GOLD FROM PARCELS OF CEMENT CRUSHED IN 1879 :—

Mining districts.	Quantity crushed.		Total produce.			Average yield per ton.		
	tons	cwt.	oz.	dwt.	gr.	oz.	dwt.	gr.
Ararat	10,654	3	2,466	12	21	0	1	9·71
Ballarat	2,725	5	352	16	16	0	2	14·14
Beechworth	..		..			..		
Castlemaine	4,034	0	367	8	12	0	1	19·71
Gippsland	..		..			..		
Maryborough	757	0	96	13	3	0	2	13·28
Sandhurst	384	0	44	12	12	0	2	7·78
Totals	18,554	8	3,328	3	16	0	3	14·09

NOTE.—The collection of the statistical information in the above table in a separate form was commenced during the quarter ending 30th June, 1872. In previous years, it has been included with quartz tailings, mullock, &c., crushed. From 1872 to 1879, inclusive, 314,884 tons 5 cwt. of cement were crushed, and yielded 68,359 oz. 9 dwt. 8 gr. of gold, being an average of 4 dwt. 8·20 gr. per ton.

AVERAGE YIELD OF GOLD FROM PARCELS OF PYRITES AND BLANKETINGS OPERATED ON IN 1879 :—

Mining districts.	Quantity operated on.		Total produce.			Average yield per ton.		
	tons	cwt.	oz.	dwt.	gr.	oz.	dwt.	gr.
Ararat	..		..			..		
Ballarat	1,287	15	4,581	0	14	3	11	3·54
Beechworth	256	10	229	17	6	0	17	22·15
Castlemaine	496	13	955	13	12	1	18	11·63
Gippsland	178	7	398	5	12	2	4	15·89
Maryborough	48	8	127	5	12	2	12	14·23
Sandhurst	3,036	10	6,722	9	0	2	4	6·83
Totals	5,304	3	13,014	11	8	2	9	1·75

NOTE.—From 1869 to 1879, inclusive, 58,040 tons 6 cwt. of pyrites, &c., were operated on, and yielded 146,905 oz. 8 dwt. 1 gr. of gold, being an average of 2 oz. 10 dwt. 14·92 gr. per ton.

QUANTITY OF VICTORIAN GOLD EXPORTED DURING 1879, AS RETURNED BY THE CUSTOMS DEPARTMENT.

oz.	dwt.
214,197	16

NOTE.—In addition to the above, 91,758 oz. 2 dwt. of New Zealand gold were shipped from this colony during the year.

PRICE OF GOLD PER OZ. DURING THE QUARTER ENDED 31ST DECEMBER, 1879 :—

Mining districts.	From			To		
	£	s.	d.	£	s.	d.
Ararat	3	13	0	4	3	0
Ballarat	3	16	6	4	3	0
Beechworth	2	10	0	4	2	6
Castlemaine	3	17	0	4	3	0
Gippsland	3	7	0	4	0	0
Maryborough	3	15	0	4	2	6
Sandhurst	3	14	6	4	1	6
Lowest and highest prices ..	2	10	0	4	3	0

REVENUE DIRECTLY DERIVED FROM THE GOLD-FIELDS DURING THE YEAR 1879:—

	£	s.	d.
Amount received for Miners' Rights	4,989	10	0
Amount received for Business Licences	570	0	0
Amount received for Leases of Auriferous and Mineral Lands	9,278	16	9
Amount received for Water-right and Searching Licences	803	10	0
Total	£15,641	16	9

NOTE.—Moneys received from holders of and applicants for Mining Leases under the heads of fees, fines, and forfeitures, are not included in this return.

LENGTH OF WATER-RACES AND THEIR APPROXIMATE COST, ON THE 31ST OF DECEMBER, 1879.

Mining districts.	Length of races.		Approximate cost.		
	miles	chains	£	s.	d.
Ararat	113	0	7,260	0	0
Ballarat	289	25	31,040	0	0
Beechworth	962	0	167,700	0	0
Castlemaine	233	12	17,702	0	0
Gippsland	162	19	10,316	0	0
Maryborough	107	37	1,778	0	0
Sandhurst	69	0	6,400	0	0
Totals	1,936	13	242,196	0	0

NOTE.—The great cost of races in some districts as compared with others is due to the construction of very expensive tunnels and tail-races.

The following particulars, which have been collected by the Mining Surveyors and Registrars, relate to the weight and cost of the stamp-heads and shanks or lifters made use of in some of the principal gold-mines in the several mining districts, and supply additional information connected with the process of crushing quartz during the year 1879.

Ararat district: stamp-heads and shanks vary in weight from 2 to 9 cwt., and cost 1*l.* 2*s.* to 4*l.* per cwt.; fall of the stamp-head, 6 to 10 in.; number of strokes made per minute, 60 to 75; quantity of quartz crushed per head per diem of 24 hours, 1 ton to 2 ton 10 cwt.; number of holes per sq. in. in the gratings used, 120 to 342; horse-power required to work each stamper, 0·5 to 1·25; quantity of water used per stamp-head in crushing, 160 to 900 gal. per hour; quantity of mercury used in the ripples per stamper, 20 to 70 lb.; quantity of mercury lost per stamp-head per week, 1·0 to 29 oz.

Ballarat district: stamp-heads and shanks vary in weight from 5 to 11 cwt., and cost 12*s.* 6*d.* to 1*l.* per cwt.; fall of stamp-head, 6 to 11 in.; number of strokes made per minute, 50 to 85; quantity of quartz crushed per head per diem of 24 hours, 1 ton to 3 ton 13 cwt.; number of holes per sq. in. in the gratings used, 64 to 256; horse-power required to work each stamper, $\frac{7}{8}$ to $1\frac{1}{2}$; quantity of water used per stamp-head in crushing, 300 to 600 gal. per hour; quantity of mercury used in the ripples per stamper, 5 to 34 lb.; quantity of mercury lost per stamp-head per week, $\frac{1}{2}$ to 6 oz.

Beechworth district: stamp-heads and shanks vary in weight from 4 to 9 cwt., and cost 1*l.* 4*s.* to 13*l.* per cwt.; fall of stamp-head, 2 to 12 in.; number of strokes made per minute, 50 to 80; quantity of quartz crushed per head per diem of 24 hours, 1 ton to 2 ton 10 cwt.; number of holes per sq. in. in the gratings used, 80 to 225; horse-power required to work each stamper, $\frac{3}{4}$ to 2; quantity of water used per stamp-head in crushing, 50 to 1200 gal. per hour; quantity of mercury used in the ripples per stamper, 12 to 100 lb.; quantity of mercury lost per stamp-head per week, $\frac{1}{4}$ to 2 oz.

Castlemaine district: stamp-heads and shanks vary in weight from 5 cwt. 2 qr. to 8 cwt. 1 qr., and cost 16*s.* 6*d.* to 1*l.* 12*s.* per cwt.; fall of the stamp-head, 7 to 12 in.; number of strokes made per minute, 60 to 80; quantity of quartz crushed per head per diem of 24 hours, 1 ton 1 cwt. to 2 tons; number of holes per sq. in. in the gratings used, 80 to 160; horse-power required to work each stamper, $\frac{2}{3}$ to 1; quantity of water used per stamp-head in crushing, 30 to 666 gal. per hour; quantity of mercury used in the ripples per stamp-head, 4 to 20 lb.; quantity of mercury lost per stamp-head per week, $\frac{1}{2}$ to 12 oz.

Gippsland district: stamp-heads and shanks vary in weight from 6 to 8 cwt.; and cost 1*l.* 12*s.* to 3*l.* per cwt.; fall of stamp-head, 6 to 12 in.; number of strokes made per minute, 45 to 84; quantity of quartz crushed per head per diem of 24 hours, 1 ton 2 cwt. to 2 ton 16 cwt.; number of holes per sq. in. in the gratings, 81 to 240; horse-power required to work each stamper, 1 to 2; quantity of water used per stamp-head in crushing, 150 to 630 gal. per hour; quantity of mercury used in the ripples per stamper, 9 to 45 lb.; quantity of mercury lost per stamp-head per week, 1 to 8 oz.

Maryborough district: stamp-heads and shanks vary in weight from 6 to 8 cwt., and cost 16*s.* to 1*l.* 11*s.* 6*d.* per cwt.; fall of stamp-head, 9 to 12 in.; number of strokes made per minute, 50 to 85; quantity of quartz crushed per head per diem of 24 hours, 1 ton 3 cwt. to 2 tons 14 cwt.; number of holes per sq. in. in the gratings used, 80 to 200; horse-power required to work each stamper, 0·85 to $1\frac{1}{4}$; quantity of water used per stamp-head in crushing, 60 to 480 gal. per hour; quantity of mercury used in the ripples per stamper, 10 to 32 lb.; quantity of mercury lost per stamp-head per week, $\frac{1}{2}$ to 8 oz.

Sandhurst district: stamp-heads and shanks vary in weight from 4 to 8 cwt., and cost 18*s.* to 1*l.* 10*s.* per cwt.; fall of stamp-head, 9 to 12 in.; number of strokes made per minute, 60 to 65; quantity of quartz crushed per head per diem of 24 hours, 1 to 8 tons; number of holes per sq. in. in the gratings used, 80 to 800; horse-power required to work each stamper, ½ to 1; quantity of water used per stamp-head in crushing, 150 to 255 gal. per hour; quantity of mercury used in the ripples per stamper, 15 to 36 lb.; quantity of mercury lost per stamp-head per week, 1 oz.

According to the Mineral Statistics for 1880, the quantity of gold raised during the year was 829,121 oz. 5 dwt., being 70,173 oz. 19 dwt. more than in 1879, and larger than any yearly yield since 1876. The estimated yield from alluvial mines was 299,926 oz., and from quartz mines 529,195 oz. Notwithstanding the further exhaustion of the auriferous deposits of the older gold-fields, the estimated yield of gold from alluvial mines shows an increase upon that of the preceding year. This increase is supposed to be due to the opening up of new gold-producing areas, in which the rich deposits have been hitherto hidden beneath deep flows of volcanic rocks. The discoveries in these tracts have been greatly facilitated by the operations of the diamond drills imported and worked by the Government; the rapid borings through dense basalt by these machines, and the information disclosed by the cores of rock obtained, have given a great impetus to alluvial mining, and have enabled mining companies to determine the downward courses of auriferous leads at distant points, and to sink shafts with precision either upon or in close proximity thereto. The principal increase in the yield of gold has, however, been obtained from quartz mines. An improvement in this class of mining, both in respect to the quantity of quartz crushed and to the average yield of gold per ton, has taken place in the Sandhurst and Castlemaine districts; but the greatest improvement is visible in the returns relating to the Ballarat district, in which the yields from quartz are shown to be far in excess of those of any previous year. The quantity of quartz raised from the mines during the past year is estimated at 968,883 tons 9 cwt., as compared with the estimate of 849,324 tons 16 cwt. for 1879. Of quartz tailings, mullock, &c., there were crushed 29,140 tons, yielding 2357 oz. of gold; and 8038 tons of pyrites, blanketings, &c., were treated, yielding 13,483 oz. of gold. The quantity of vein-quartz crushed and the average yield of gold per ton in the several districts of the Colony were as follow:—Ararat: quartz crushed, 83,853 tons; yield per ton, 19 dwt. 15·05 gr.; Ballarat: 448,841 tons; 7 dwt. 14·48 gr.; Beechworth: 48,020 tons; 12 dwt. 21·54 gr.; Castlemaine: 80,720 tons; 8 dwt. 20·64 gr.; Gippsland: 23,767 tons; 1 oz. 3 dwt. 11·69 gr.; Maryborough: 43,587 tons; 12 dwt. 11·18 gr.; Sandhurst: 239,894 tons; 10 dwt. 18·68 gr. Apart from the large quantities of quartz crushed, these returns show a gratifying increase on the average yields of gold per ton in every mining district except Ararat. The numbers of miners employed in alluvial and quartz mining on December 31, 1880, were as follows:—Ararat: alluvial, 2049, and quartz, 801; Ballarat: 4225 and 4911; Beechworth: 3706 and 1347; Castlemaine: 3360 and 1393; Gippsland: 1891 and 470; Maryborough: 5673 and 2154; Sandhurst: 2012 and 4576. Total alluvial miners, 22,916; quartz, 15,652; grand total, 38,568, being an increase of 1000 over 1879. The number of Chinese engaged in mining operations in Victoria continues to decrease; on December 31, the number was 8486, or 624 less than in 1879. Dividing the quantity of gold exported and received into the Mint among the miners employed in 1880, the average per man in alluvial mines is 49*l.* 14*s.* 2*d.*; and in quartz mines, 129*l.* 11*s.* 7¾*d.* The approximate area of auriferous ground over which mining operations have extended up to the end of 1880 is 1235 sq. miles; and the number of distinct quartz reefs proved to be auriferous is 3630. The total area occupied as "mining claims" under the provisions of the bye-laws of the several mining boards was 35,126 acres, and the area held under leases from the Crown was 24,430 acres. In the exploration of the country for quartz veins, shafts continue to be extended in depth throughout the gold-fields.

The total quantity of gold raised in Victoria from the period of its first discovery in 1851 to the end of 1880 is given by two official statements respectively as follows:—

a. 49,549,051 oz. 16 dwt., value, at 4*l.* per oz., 198,196,206*l.*
b. 49,646,717 oz., „ „ „ 198,586,868*l.*

The table on pp. 642–3 shows the yield of gold from parcels of quartz raised during the 1st quarter of 1880 from some of the deepest mines in Victoria, with the depth of their deepest shafts.

Victoria auriferous reefs.—The characteristics of the auriferous quartz reefs or veins of Victoria have been carefully studied by William Nicholas, whose observations exhibit many facts of great value. Quartz mining is now the most important branch of gold-mining in Victoria, the yield from the reefs exceeding that from the alluvions by many thousand ounces per annum. Reefs are worked on several gold-fields at more than 1000 ft. beneath the surface; shafts, levels, and cross-cuts can be measured by hundreds of miles; and the outlay of capital necessary to the development of quartz mines can be calculated by millions of pounds sterling. A study of the characteristics of the auriferous quartz veins, and the laws which regulate them, is therefore highly interesting; and Nicholas for many years devoted leisure time in collecting important facts relating to the strike, dip or underlie, and width of reefs, and the dip of the shoot of gold and quartz in the reefs, in order that he might render quartz mining less a matter of chance than it has been in the

District, division, and subdivision.	Name of company.	Name of reef.	Depth at which quartz got.	Quantity crushed.	Average yield of gold per ton.	Width of reef.
			ft.	tons.	oz. dwt. gr.	ft. in.
ARARAT.						
Ararat div.	Pleasant Creek ..	Scotchman's Flat	1,200	1,128	1 15 2	..
		Cross	850	1,354	1 6 0	..
	Oriental..	Scotchman's.. ..	1,120	2,579	1 10 19	..
BALLARAT.						
Central div.	Temperance	Band of Hope ..	400 to 950	1,500	0 7 5	2 0[2]
Southern div.	New Kangaroo ..	Staffordshire.. ..	278	1,753	0 4 2	6 to 13 0[3]
Buninyong div.	Imperial Q. M. ..	Hiscock's	112	2,103	0 6 21	20 0
Creswick div..	Port Phillip	Clunes	80 to 990	14,523	0 5 23[5]	2 to 30 0
	New North Clunes	Clunes	200 to 1100	2,052	0 10 2[5]	2 to 7 0
Steiglitz subdiv.	Cleary's Freehold	.. ..	140	1	4 0 0	6 in. to 10 in.[6]
Blackwood div. and Blue Mountain S. subdiv.	Sultan	Sultan and others	400 to 750	1,665	0 13 12	6 in. to 6 ft.
BEECHWORTH.						
Beechworth div.	Reform	Reform, Myrtleford.	450	1,420	0 6 15	10 0
Yackandandah S. subdiv.	Shackenburg Bros.	Morning Star ..	60	64	1 18 2	4 0
Buckland div.	Davis and Co. ..	Tiddle-de-addledee	350	158	4 16 7	..
	J. A. Wallace ..	Land Tax	600	180	1 10 0	..
	Page and Co. ..	.. ..	240	38	2 4 5	..
Alexandra subdiv.	J. Ferguson	Accident	55	9	2 7 21	1 0
Gaffney's Creek subdiv.	Laurnville	Homeward Bound	150	35	0 4 20	8 0[8]
Wood's Point subdiv.	Sir John Franklin	Ford's	200	150	0 16 0	2 0
Big River subdiv.	Londonderry ..	Railway..	300	600	0 3 9	4 0
Jamieson subdiv.	Clancy's..	Gleeson's Lease ..	170	32	3 9 6	1 0
CASTLEMAINE.						
Castlemaine div.	Central Wattle Gully.	Wattle Gully ..	350	503	0 6 23	irregular[9]
Fryer's Creek div.	New Era	Ferron's..	70 to 400	6,226	0 4 22	6 in. to 20 ft.
	Rowe Bros.	Cattle's	160 to 260	1,673	0 4 15	5 to 20 0
Hepburn div..	Rising Star	Wilson's..	195	120	1 3 16	5 6
Taradale and Kyneton subdiv.	United Kingdom..	United Kingdom..	50[10]	143	0 3 1	3 0
Tarrangower div..	North British ..	Parkin's Reef ..	500	452	1 19 12	4 0
	German Reef ..	German..	360	369	3 17 3	3 6
GIPPSLAND.						
Mitchell R. and Boggy Ck. subdiv.	Galloway	Galloway	60	200	0 6 12	14 0
Crooked R. div.	.. ..	.. ..	..	..	..	..
Stringer's Creek div.	Long Tunnel ..	Cohen's	[14]343 to 623	4,072	1 4 23	12 0
MARYBOROUGH.						
Maryborough div.	Bristol Hill	Western Reef ..	500 to 550	528	0 4 14	1 to 6 0
		Eastern Reef ..	270 to 300	342	0 2 20	6 in. to 4 ft.[15]
Amherst div..	Union	Church Hill	250	115	5 13 1	1 0
Dunolly and Tarnagulla div.	Queen's Birthday	Bealiba	400 to 520	1,710	0 14 14	6 0
	Welcome	Welcome	240	53	4 2 19	1 9
	North Birthday ..	Bealiba	200 to 300	1,156	1 4 16	3 0
SANDHURST.						
Sandhurst div.	Garden Gully United.	Garden Gully ..	750	4,015	1 9 11	18 in. to 4 ft.
	Unity	Garden Gully ..	800	848	0 6 21	2 to 10 0
	Little Chum	New Chum	580	124	1 6 1	1 6
	Central Catherine	Catherine	580, 640, 700	1,359	0 7 16	1 to 3 0
Heathcote div. and Waranga S. subdiv.	Alabama and Butler.	Butler's	450	480	0 10 0	0 6

[1] Still sinking.
[2] A well-defined lode.
[3] Lode well-defined at 950-ft. level.
[4] Not working at present.
[5] Including pyrites.
[6] This reef was first struck on the surface, and the trial crushing yielded 3 oz. to the ton.
[7] Sinking has been stopped for the present for the purpose of prospecting at the 900-ft. level. Another plunger has been put in, and there are now four plungers at work in the shaft.
[8] Granite formation.

Average yield of gold per ton.	Width of reef.
oz. dwt. gr.	ft. in.
1 15 2	..
1 6 0	..
1 10 19	..
0 7 5	2 0[2]
0 4 2	6 to 13 0
0 6 21	20 0
0 5 23[5]	2 to 30 0
0 10 2[5]	2 to 7 0
4 0 0	6 in. to 10 in.[6]
0 13 12	6 in. to 6 ft.
0 6 15	10 0
1 18 2	4 0
4 16 7	..
1 10 0	..
2 4 5	..
2 7 21	1 0
0 4 20	8 0[8]
0 16 0	2 0
0 3 9	4 0
3 9 6	1 0
0 6 23	irregular[9]
0 4 22	6 in. to 20 ft.
0 4 15	5 to 20 0
1 3 16	5 6
0 3 1	3 0
1 19 12	4 0
3 17 3	3 6
0 6 12	14 0
..	..
1 4 23	12 0
0 4 14	1 to 6 0
0 2 20	6 in. to 4 ft.[15]
5 13 1	1 0
0 14 14	6 0
4 2 19	1 9
1 4 16	3 0
1 9 11	18 in. to 4 ft.
0 6 21	2 to 10 0
1 6 1	1 6
0 7 16	1 to 3 0
0 10 0	0 6

present for the pur-
l. Another plunger
plungers at work in

Dip of reef.	Dip of quartz.	Strike of reef.	Name of company.	Name of reef.	Depth of shaft.	Depth of deepest level.	Depth of deepest cross-cut.
					ft.	ft.	ft.
			Magdala[1]	.. ..	2333	2002	2002
			Newington	.. ..	1940	1510	1510
			Prince Patrick	.. ..	1784	1500	1500
			Prince Alfred[1]	.. ..	1614	1026	1026
..	..	..	Crown Cross United ..	.. ..	1313	1000	1000
..	..	..	Oriental[1]	.. ..	1275	1238	1238
..	..	..	South Scotchman's ..	.. ..	1262	1252	1252
			Pleasant Creek	.. ..	1220	1200	1200
			Extended Cross Reef	.. ..	1170	1070	1070
			West Scotchman's ..	.. ..	1052	800	800
			Scotchman's United ..	.. ..	1018	1000	1000
W. 3 ft. in 6 ft.	N.	N. and S.	Temperance	Band of Hope[8] ..	955	950	950
W. 70°	S.	..	Little Hopewell	Staffordshire ..	520	500	500
E. 66°	N.	N. 8° W.	Imperial Q. M.	Hiscock' '	410	400	400
4 reefs E. 30°; 2 reefs W. 30°	N.	W. 15°	Port Phillip	Clunes	1193	1090	1090
W. 15°	N.	N. 8° E.	New North Clunes ..	Clunes	1105	1105	1105
E. and W.	E.	..	.. ..	.. ..	..	..	..
Varies	Varies	N. 11° W.	Sultan	Sultan and others[7]	914	900	900
W.	S.	Northerly	Dale and Co.	Excelsior, Wooragee.	310	180	310
W. 80°	Vertical	N. 10° E.	Bigelow and Clingan..	Homeward Bound	450	420	..
..	..	..	.. ..	.. ..	..	..	..
..	..	..	.. ..	.. ..	..	..	..
..	..	..	.. ..	.. ..	..	..	..
S.W. 30°	S.W. 30°	N. 22° W.	.. ..	.. ..	..	..	..
Westerly	N.W. 33°	N.W. 33°	.. ..	.. ..	..	..	..
S.W. 70°	S.W. 70°	N. 52° W.[8]	.. ..	.. ..	..	..	..
Vertical	..	N. 33° W.	.. ..	.. ..	..	..	..
E.	..	N. 27° W.	.. ..	.. ..	..	..	..
..	..	..	.. ..	.. ..	..	..	..
E. 36°	..	N. 14° W.	New Era	Ferron's..	514	500	500
W. 50°	N. 1 in 8	N. 5° E.	Rowe Bros.	Cattle's	220	175	175
W. 60°	S. 30°	N. 20° W.	.. ..	.. ..	..	..	..
..	..	..	.. ..	.. ..	..	..	..
W. 80°	S. 75°	N. 12° W.	Eaglehawk Union ..	Eaglehawk[11].. ..	1220	1000	1200
E. 78°	S. 45°	N. 15° W.	North British	Parkin's[18]	500	500	500
..	..	..	.. ..	.. ..	..	..	..
..	..	..	Good Hope[18]	Good Hope	700	500	700
W. 80°	N. 30°	N.W. 19°	Long Tunnel	Cohen's	735	723	723
			Walhalla	Cohen's	615	585	585
W. 65°	..	N. 12° W.	Bristol Hill..	Western Reef ..	628	600	600
W. 35°	..	N. 10° E.		Eastern Reef ..	310	300	300
N. 36°	E. and W.	N.	Union	Church Hill	254	250	250
E. and W.	S.	N. 18° W.					
E.	S.	N. 16° W.	Queen's Birthday ..	Bealiba[1]	556	520	520
E.	N. and S.	N. 18° W.	King's Birthday ..	Bealiba[1]	390	233	233
			Lansell's 180	Victoria[16]	1476	1200	1460
			Great Extended Hustler's.	Hustler's[17]	1368	1350	1350
..	..	..	Carlisle, N. Garden Gully, and Passby United.	Garden Gully[16] ..	1340	854	1320
			Great Extended Hustler's Reef Tribute.	Hustler's[16]	1264	1200	1250
N. 1 in 4	..	..	Alabama and Butler..	Butler's Reef ..	570	500	500

9 Leaders extending 130 ft. W. of foot-wall.
10 A new shaft sunk during the quarter.
11 Driving E. to strike the reef.
12 Commenced sinking below 500-ft. level.
13 Preparing machinery, &c., to drive the No. 4 level.

14 Below adit level.
15 Broken and irregular.
16 Not sinking.
17 Not sinking. Reef struck at 1240-ft. and 1350-ft. cross-cuts, but shows no gold.

past. The data collected have been classified under two principal divisions, viz. reefs that occur in Lower Silurian and in Upper Silurian rocks.

Strike of reefs.—Of 998 reefs, 841 are situated in the Lower, and 157 in the Upper Silurian rocks. These are subdivided into reefs bearing W. of N. and E. of N. Of those in the first-named class of rocks, 554 had an average strike of N. 20° W., and 117 in the latter had an average strike of N. 34° W.; whilst there were 287 reefs in the Lower Silurian that possessed a strike E. of N. averaging N. 11° E., and 40 reefs in the Upper which had a strike of N. 27° E. From these figures, it will be seen that out of a total number of 998 veins in both formations, 671 had a direction W. of N. and only 327 ran E. of N. The variation of these reefs to W. and E. of the true N. point in the Lower Silurian was just one-half that in the Upper Silurian rocks; or, to put it in other words, in the first-named rocks, the average strike of the reefs W. and E. of N. added together makes but 31°, whilst that of those in the second makes 61°. It appears then that the auriferous veins in the Lower Silurian formation are much more nearly N. and S. than those in the Upper. As a rule, the auriferous veins run parallel with the strata in which they are enclosed, and the greater number of the most extensively wrought and richest veins in Victoria strike W. of N.

Groups of reefs.—When the reefs on the gold-fields are plotted on a geological sketch-map of Victoria, it becomes manifest that they are naturally divided into seven groups, of which two are important and five of less importance. The two main groups or belts are well defined, have a general direction N. and S., and are in the Lower Silurian strata. The E. one embraces (commencing from the N. extremity and going S.) the undermentioned gold-fields, viz.—Kamarooka, Raywood, Sandhurst, Marong, Castlemaine, Fryer's Creek, Maldon, Newstead, Yandoit, Taradale, Daylesford, Gordon, Blackwood, Ballan, and Steiglitz, at the S. extremity. It contains 774 distinct quartz reefs actually proved to be auriferous. The W. main group or belt comprises—Wedderburn, at the N. end; Kingower, Inglewood, Tarnagulla, Dunolly, Maryborough, Talbot, Clunes, Creswick, Ballarat, Buninyong, Smythesdale, and Bulldog, at the S. end. There are 535 known auriferous reefs in this belt. These two great belts are separated by the 144th meridian of longitude on the map of Victoria, and physically by a barren and depressed strip of strata 15 miles in width.

Of the five groups of lesser importance, two lie in the Upper Silurian and three in the Lower Silurian rocks.

In the first group (which lies E. of the main belts) are the following gold-fields, commencing with the most N.:—Rushworth, Whroo, Coy's diggings, Redcastle, Heathcote, Tooborac, Kilmore, Yea, St. Andrews, and Mornington. (Near the last-named place are 2 undeveloped auriferous reefs.) It contains 530 distinct auriferous reefs.

The second group in the Upper Silurian contains, beginning at the S. end and going N.:—Stockyard Creek gold-field, Red Hill diggings, Russell's Creek, Walhalla, Jericho, Donnelly's Creek, Wood's Point, Gaffney's Creek, Big River, Jamieson, Alexandra; and on the N. of the great granite outcrop, Baddaginnie, near which place there are reported to be 6 auriferous reefs which have been but slightly wrought. The auriferous reefs in this group number 323, and the course of the group is N.W. In these two lesser groups, many considerable tracts of Upper Silurian strata intervene between the gold-fields, and are either deficient in auriferous reefs, or the reefs in them are not proved.

The third group to the E. is in what is believed to be Lower Silurian rocks, and it is the most considerable of the five smaller groups. Commencing at its N. extremity and running S., it comprises the Chiltern gold-field, Beechworth, Yackandandah, Myrtleford, Morse's Creek [Bright], Harrietville, Mitta Mitta, Omeo, Crooked River, and Boggy Creek. This group strikes W. of N., and contains 893 known auriferous reefs.

On the W. side of the two great belts, lie the fourth and fifth groups of lesser importance in Lower Silurian strata.

The fourth contains St. Arnaud, Stuartmill, Redbank, Landsborough, Avoca, Barkly, and Raglan; in which gold-fields, 151 distinct quartz reefs have been proved to be auriferous.

The fifth, last, and most W. group comprises the Stawell gold-fields, Great Western, Ararat, and Moyston; and in this group are 63 distinct auriferous reefs.

With the exception of some 10 unimportant auriferous reefs, all that are known to exist in Victoria are included in one or other of the seven groups above described.

In Victoria, the veins run at right angles to the main dividing range; but it will be found that they run parallel with the principal spurs or tributary ranges of the main divide, and by a study of the map it will be noticed that the general direction of these ranges or spurs on the gold-fields is N. or N.W. at about right angles to the main dividing range. For example, in the E. part of Victoria, where the divide bends round to N.E., and is well marked, the groups (as has been noticed) have a course N.W. In the central part of Victoria, where the divide runs almost due E. and W., the reefs in the two great groups or belts run more nearly N. and S.; whilst in the W. groups, where the divide is low and not well defined, the course of the comparatively important tributary spurs is N.W., and to them the reefs run parallel. Also, several of the groups are more or less separated by low depressed country, in which are the valleys of rivers: another physical proof that the high lands trend in a N. and S. direction.

Cross-reefs.—Auriferous cross-reefs occur in the Lower Silurian formation at Steiglitz, Ovens district, Maryborough, Redbank, Dunolly, St. Arnaud, Heathcote, Pleasant Creek, Grant, and Crooked River, to the number of 61, of which 53 have an average strike of N. 60° W., and 8 have an average strike of N. 74° E. In the Upper Silurian, cross-reefs are found at Rushworth, Whroo, Coy's diggings, and Redcastle, to the number of 24, of which 15 have an average strike of N. 85° W., and 9 of N. 71° E. These figures exemplify that Victoria is not destitute of veins running E. and W., which in other countries is the direction of the predominating strike of mineral and metalliferous lodes or veins. R. A. F. Murray mentions the discovery of 2 cross-reefs at Wilson's Promontory, which have a strike of N. 55° W., and dip S. 35° W., but they had not been proved auriferous. Only one of them, however, had been prospected, and that to a slight extent. Krausé reported an auriferous cross-reef at Ararat, 18 in. wide, with a strike of W. 30° S. (across the strike of the bounding rock), and a dip of N. 80°; it was worked to a depth of 240 ft. below the surface, and the highest yield of gold obtained from it was 2¼ oz. per ton.

Dip [Underlie] of reefs.—Of the dips of auriferous veins in 134 instances, 78 in the Lower Silurian had an average of 61° W., and 22 of 62° E.; and 19 in the Upper Silurian formation averaged 72° W., and 15 had a mean dip of 49° E. Out of the 134, 97 dipped to W., and 37 to E. In addition, Nicholas got the direction of the dip, but was not able to obtain the angle, of 41 other reefs situated in the Lower Silurian, 33 of which underlay to W. and 8 to E.; and also found records of 16 vertical reefs. From the limited data and information gathered, it does not appear that the richness or poverty of auriferous reefs is affected by the variation of the angle of underlie. The greater number of the reefs seem, however, to have a dip of about 60°. The majority of the most important reefs in Victoria appear to have a W. underlie, although there are many rich reefs that dip E. Nicholas also mentions that the saddle-formed reefs so characteristic of the master lodes of the Sandhurst gold-field are not confined to that field, but occur also at Clunes, Blackwood, Lauriston, Hepburn, Inglewood, and in the Bonang Range in Gippsland.

Shoot of gold.—Respecting the shoot of gold, Nicholas got particulars of the dip of 57 "pay chimneys" (as they are called in California) or shoots, 25 of which dipped to N., 28 to S., and 4 were vertical; the prevailing angle of the N. and S. shoots was between 25° and 50°. The information obtainable under this head is unsatisfactory, as there are apparently but few persons who have thought this subject of sufficient importance to have qualified themselves to be able to say, even approximately, whether the general direction of the shoot of gold is N., S., or vertical. Too frequently, when remarks are made on this subject, inquirers are checked by finding it stated that the shoot of gold varies. There will probably be some difficulty in defining the dip of the shoot in reefs that contain fine gold evenly distributed; but in all cases, if a longitudinal or working section were kept, the course of the vein worked out would show the dip of the shoot of quartz, with which the shoot of gold usually conforms. In Nicholas' own experience, he has found that the shoot of quartz is invariably at right angles to the lines of striation on the walls or laminations of reefs, or to the heads or joints in the bounding rocks. In California, it has been observed that the pay-chimneys run with the lines of striation. That the dip of the shoot of quartz or gold should be known, is a matter of the first importance in the working of all mines, and especially to adjoining mines.

Width of reefs.—Nicholas gathered the widths of 286 reefs. Of these, 237 were in Lower Silurian rocks, and 49 in Upper Silurian. He divided these widths into three divisions, viz. (1) under 5 ft., (2) over 5 and under 10 ft., (3) over 10 ft. Of the 237 reefs in the Lower Silurian, 168 were under 5 ft., and averaged 2 ft. 5 in.; 45 were over 5 ft., and averaged 6 ft. 8 in.; and 24 were over 10 ft., and averaged 29 ft. Of the 49 reefs in the Upper Silurian, 44 were under 5 ft., and averaged 2 ft. 1 in.; 1 was over 5 ft. (or 8 ft. 5 in.); and 4 were over 10 ft., and averaged 15 ft. 6 in. From the above figures, it will be seen that the reefs in the Lower Silurian are much wider than those in the Upper Silurian formation, and it is found that the thickest reefs have proved the richest and most extensively worked in Victoria.

Laminated reefs.—In the catalogue of auriferous quartz specimens (Victorian) in the collection of the Survey department, of 108 of the most important reefs, from which fair samples were obtained, 59 had a laminated structure. The same data show that, of the 108 reefs, 48 contained gold in cavities; 9 specimens only were found to contain gold in the solid quartz; and in the laminations, gold was observed to occur in 24 reefs. These facts point out that the greater part of the free gold in our reefs is not enveloped in solid quartz, but occurs in a comparatively loose state in the cavities and laminations, with clay-slate, galena, pyrites, and zinc-blende: from which, an inference may be drawn, that the freer are the tailings run off from a quartz-crushing mill from any other substance than quartz, the less is the loss of gold.

Dykes.—It is well known that basaltic dykes are associated with the main lodes of the Bendigo gold-field, but they are not confined in this respect to that field. In other gold-mining districts, in the Lower Silurian rocks, they have also been found; for example, at Castlemaine, a basalt dyke, 2 ft. in width, has been discovered in working the Eureka reef; another dyke, varying in width from 18 in. to 2 ft., has been met with in mining the Shelback reef, Barker's Creek; and a third, having a regular course, and a thickness of 6 to 24 in., was discovered in the Wheal Terrill mine, Wattle Gully. Murray reports that, at Ballarat, a few dykes similar to those found at Sandhurst occur; Norman Taylor, that black basaltic dykes were found in the Waterloo, Argyle, Albion, and South Scotchman mines at Pleasant Creek.

These dykes appear to conform in strike [direction] with the auriferous veins with which they are associated; they cut through the veins and strata at all angles; have a tortuous winding course; occasionally, when they have been intercepted by a reef, they follow its underlie for short distances; or they are found more frequently to fault the reefs; in width, they are irregular, varying from 1 in. to 9 ft. 6 in.; and dykes have been found to split into two or more streams. Some dykes consist of compact hard basalt containing olivine, and it would be difficult, if not impossible, to distinguish the rock of which they are composed from the newer basalts which are spread over such large areas in Victoria; whilst others are decomposed into white, yellow, grey, and speckled brownish clays. By miners, they are now considered certain guides to reefs, and Nicholas pointed this out as far back as 1863. If dykes can be said to have a dip, it is found, in working reefs, most frequently to be opposite to that of the reefs they intersect; but their general direction will no doubt prove to be vertical. These dykes record, by lines of striation and polished faces, movements on either side of them in the strata.

Of auriferous lodes or reefs in other countries, it is observed that the strike most common is N. and S., and that there are a half-dozen mines in which the lodes may be classed as E. and W. or cross-reefs. It is stated, however, that the veins in Minas Geraes, Brazil, strike most frequently E. and W. In Northern Mexico, and in Virginia, Orange, and Buckingham counties, United States of America, the strike of the veins deviates to the E. of N., whilst those in California, British North America, and Oregon, U.S.A., strike either N. and S. or deviate to the W. The E. and W. lodes are generally poor when compared with the N. and S. The fact noted by Henwood, that the veins in Brazil run parallel with the mountain chains, has also been observed to be true in California. The lodes dip both E. and W., and the average dip of those of which the angle is given is 55°.

Of 28 veins, 8 under 5 ft. averaged 2 ft. 9 in.; 3 over 5 ft. averaged 7 ft.; and 17 over 10 ft. averaged 27 ft. In common with Victorian reefs, these lodes or veins are proved to be ever varying in thickness, to have rich gold-bearing shoots or pay-chimneys, and poor zones, which succeed one another vertically or horizontally; to be laminated, have slickensides, dykes, and slides; to be nipped out—the walls of the veins coming together; and to possess the same mineral composition, consisting most commonly of quartz, arsenical and iron-pyrites, galena, zinc-blende, copper-pyrites, silver, antimony, calcspar. With regard to the last-named mineral, in Nicholas' opinion, although it has hitherto only rarely been found in auriferous veins in Victoria, and then mostly in small quantities, it will be found to occur commonly and in quantity as the reefs are mined to greater depths. In support of this opinion, he mentions that the mineral has been found in nearly solid quartz, got from 1687 ft. in depth, in the Magdala mine, Pleasant Creek; in compact quartz, from 560 ft. in depth in the Victoria reef, Sandhurst; and it has been observed in quartz from the Garden Gully reef, Hustler's, Brown's; "lava dyke," on the Johnson's, at Sandhurst; in a "lava dyke" associated with the Wattle Gully reef, Castlemaine; and in all these mines at considerable depths. It has also been found (in quantity) in the Shamrock claim, Gooley's Creek, and other Gippsland mines. The calcite observed in the quartz from the Magdala mine and Victoria reef occurred in thin veins in compact quartz, and was only discovered after careful examination; in some of the other cases mentioned, it was found in cavities. In the "lava dykes," it sometimes occurs in thick seams. Whether the occurrence of this mineral in quantity in our reefs will have any effect on their auriferous character, is a matter of speculation; but it is not likely that the reefs will be richer for its presence. It is, however, probable that the reefs will contain more metals and minerals, such as silver, copper, lead-ore, and pyrites. But as calcspar has not yet been found to exist to any large extent in the reefs down to 1000 ft., it is not desirable at present to speculate on its favourable or non-favourable influence on the gold-bearing qualities of the reefs. Calcite is associated with gold in the veins worked in Queensland, Brazil, and Virginia.

Passing from generalities, separate accounts will now be given of the most interesting gold-fields, ranging them alphabetically under their districts.

Ararat.—According to Krausé's report (Oct. 7, 1874), a marked feature, at once noticed by a visitor from the central gold-fields, is the absence of shallow alluvial "ground" in this district—a feature which is certainly not to be attributed to a lesser amount of denudation during Post-Tertiary times, but rather to the character of the denuded material itself. At Castlemaine, Sandhurst, and other fields, the newly-eroded valleys were filled by the detritus of highly auriferous Pliocene gravels, and the abrased caps of rich quartz lodes. On this field, the denuded rocks were Silurian schist, quartz reefs, and, principally, the Upper Newer Pliocene drifts, neither of which appears to have possessed the precious metal in quantity. Except in the immediate proximity to Older

Tertiary hills, the alluvium in Ararat gullies and creeks is therefore, as a rule, absolutely barren.

From the large extent of country occupied by the drifts of the Upper Newer Pliocene (recent gold-drift), and the equable manner of their deposition, there is little doubt as to their marine origin, and that they have been left by a slowly receding sea. They consist of mixed clay and angular gravel, from a capping to upwards of 100 ft. in thickness, and layers of ferruginous cement, the constituent gravels of which are angular. They first occur at an elevation of 1100 ft. above the sea, and have their largest extent N. and N.E. of the township of Ararat, where they cover "deep ground, at the Lower Wet lead, Sawpit Flat, Three-mile Creek, &c. The configuration of the Older Pliocene surface has been greatly modified by the levelling influence of these latter deposits, and a considerable breadth of, no doubt, richly auriferous country is as effectually hidden beneath the clay drifts as under the lava plains of the Hopkins farther S. Indeed, observing from a miner's point of view, the search for the deep leads under the drift mantle, while accompanied by the same amount of uncertainty which attaches to the position and mining capabilities of the sub-basaltic gutters, is rendered even more difficult by the extra labour requisite in securing the mine against the lateral thrust of a permeable stratum. Here and there, where the newer cement rests directly on the bed-rock, it has been removed for crushing; but the results have in all cases been discouraging to the miner, and it would appear that no gold in workable quantities has been found in any of the Upper Newer Pliocene beds.

Most of the "leads" now working in this mining division are referable to the Lower Newer Pliocene (older gold-drift) period. They frequently rise at an elevation of 1250 ft. above sea-level, and have been traced downwards to 800 ft. At their heads, they follow pretty generally the course of existing drainage-channels; but as the latter gain the low land, covered by newer drift, and the Silurian rock forms no longer the banks of the valleys, then the leads cease to conform, and their course is often transverse to existing watershed lines. From the manner of their occurrence, these deposits are clearly the result of fluviatile agency; yet the fact of large sub-angular boulders of quartz being found deposited at the very source of certain leads, where little or no fluvial action can have taken place, tends to show either that they are the denuded remnants of Older Pliocene beds removed from a much higher altitude, or else that the upper valleys of the leads were inlets to a Lower Pliocene ocean.

With one exception, the Dividing Range forms the main axis alike for the Newer Tertiary and the modern drainage systems. On the seaward side are two main courses of auriferous leads trending S. towards a junction below the Burrumbeep Preemptive Section. The E. course starts from the valley of the Warayatkin Creek, receives the Mullock Bank, Upper Wet, Ararat, and Kangaroo Range leads, with their network of tributaries, and immerges under the basalt immediately E. of the township of Ararat. The W. course begins under the Main Range in the valley of the Deenicull Creek, and admits the Blackman's, Sydney Flat, Phillips', Gibson's, Cathcart, and other leads. The lower portion of the E. course is covered by basalt; that of the W. course, by Upper Newer Pliocene drift. On both leads, the miner has encountered such difficulties, chiefly in the excessive influx of water, as to submit to the cessation of mine work at a comparatively early stage. It is an important fact, however, that most or all of the main leads have proved remuneratively auriferous up to the time of their abandonment. With respect to this locality, it is, in Krausé's opinion, infinitely less a matter of scientific conjecture as to the existence and position of auriferous deep leads, than a simple question of procuring capital for the resumption of mining operations.

On the W. side of the Main Range, are principally the Rocky Point, Opossum Gully, and Port Curtis leads, which have been profitably wrought for a length of several miles over a granite bed-rock. In their lower course, the leads are confined within the steep rocky banks of the present valleys, and as the fall of the latter increases, the older drift has been in places removed by the scour of the modern stream, and re-distributed as a shallow alluvium, which contains the gold so fine and scattered as to become practically unworkable. This is the only instance in which the mining term "lost lead" assumes a geological meaning.

Independently of palæontological evidence, and judging from their physical distribution only, the lowest gold-drifts (Older Pliocene) have always been classed as marine deposits, and it is impossible to come to any other conclusion when the formation is studied on this gold-field. They occur at uniform levels: first, as outliers 1100 ft. above sea-level, occupying the crests of isolated hills, often several miles asunder, on either side of the Main Range; then, as the country falls S. away from the great axis, their outline increases around hills and flanks of ridges; and finally, at an altitude of 600 ft. stretch in an unbroken gently-sloping plain down to the Wimmera basin. By imagining an inclined plane between the highest point at which the drifts appear at Ararat, and the lowest level to which the Four-post lead at Stawell has been traced—whether this inclination be due to the natural configuration of the surface of the Palæozoic rocks, or caused by subsequent gradual upheaval, does not matter at present—the geological horizon of the Older Pliocene era is obtained. Five miles north of Stawell, as far as present information goes, are the uppermost beds of the group, consisting of soft, mottled, brecciated sandstones, and ferruginous sand and loam with concretionary ironstone, shelly conglomerate and fossil marine shells (chiefly *Astarte* and casts of univalves). Below this are well-rounded quartz gravels, conglomerate (cement), and coarse grit—the oldest gold-drift. At Ararat are only deposits of the latter description—the upper beds have either been removed by denudation or (if the declivity pre-existed) were never precipitated along the shallow margin of the Pliocene ocean. A few miles farther N. of the Stawell leads, beds of marine shells of pronounced Miocene age are said to occur, and this would complete the analogy between the Tertiaries of these gold-fields and those exposed in cliff sections near Point Castries, and probably also those of the Moorabool valley, near Maude.

The older leads, though but sparingly represented on the S. side of the Dividing Range, have proved to be exceedingly rich in gold. Bridal Hill, Canton lead, Flint Hill, Union Jack lead, Surface Hill, and Cathcart Hill are the principal representatives of the oldest drift in the neighbourhood of Ararat. The depth of the Flint Hill drift is from 20 to 40 ft., and contains gold distributed throughout the whole thickness. The coarse "shotty" gold is usually, but not invariably, on the bottom or bed-rock. Another characteristic instance of the immediate physical relation of the Pliocene gold-drifts is offered in the locality of Cathcart. This hill is composed of a cemented drift of gravel and metamorphic schist, 30 ft. in thickness, nearly the whole of which is more or less auriferous.

It is a noteworthy fact that not a single well-defined quartz reef in the neighbourhood of Ararat has been found payably auriferous at the levels to which they have been tested. The only lodes that have been worked to advantage are those irregular veins showing no defined casings, and the latter much disturbed, and leaving spaces which are filled up with the rubble of the adjoining rock mass. It is, however, necessary to state that in no instance has the depth to which the quartz workings extend been below the level of the older gold-drifts in the immediate vicinity of the reef. These remarks refer simply to the reefs within the area of the S. half-sheet of the survey, and do not apply to the Moyston, Rhymney and Port Curtis reefs. Campbell's reef and Rhymney reef are tolerably well-defined lodes, that have been profitably wrought at 600 ft. and 200 ft. respectively. Both are in metamorphic-schist country. Bourke's reef, although it has proved highly auriferous at a shallower level than the contiguous older leads, is a very irregular flat lode cutting through decomposed granite.

A second report by Krausé, dated July 1, 1875, deals with the N. portion of this gold-field. Examination of the mode of occurrence of the Tertiary and Post-Tertiary rocks in the N. area of the survey did not augment to any great degree the knowledge previously held. The information gained is with regard to the extent of the deposits, affecting the economic bearing of the inquiry.

1. The Warayatkin fluvial leads, in the valleys of the Sawpit Flat and Three-mile Creek, underlie the alluvial flats just mentioned, and trend towards a junction beneath the basalt at the Green Hill swamp. The sinking is principally through clays, partly sandy, partly unctuous and bituminous; fine sub-angular gravel of quartz and ironstone containing drift-wood, and layers of plastic clay containing an abundance of nodules of bisulphuret of iron, 4 to 8 ft. thick. The total depth is 90 to 150 ft. In the bottom layer of clay, thin patches and streaks of blue iron earth (phosphate of iron) are found. This mineral (vivianite) has been hitherto found in this colony only in conjunction with volcanic rocks, and it is probable that in this instance, too, it has been derived from disintegrated basalt, a flow of which (now covered by the newer clay-drift) extends up the lead-valley some distance from the visible basalt boundary.

2. The Main Hopkins lead lies under the basaltic plain on the E. side of the river Hopkins, from Ararat to Jackson's Creek, a length of about 7 miles. A union of the Black, Caledonian, and Warayatkin leads probably takes place at or near the Racecourse Reserve. Tributaries join on the W. from the Kangaroo Range, and on the E. from the valleys of the Gorrinn and Jackson's creeks. The former have been proved to be highly auriferous; of the latter nothing is known beyond the fact that they rise in Silurian country, which is intersected by quartz reefs and capped by quartz gravel-drift not hitherto worked upon. The trunk lead runs S., and most likely passes under the valley of Jackson's Creek, at a point about a mile above its confluence with the river Hopkins. Beyond this place, indications are wanting. The possibility is that the sub-basaltic Silurian rocks are auriferous, and may contribute towards the "feeding" of the main drainage channel; but a glance at the sketch-map shows it to be more probable that from Jackson's Creek for several miles S. the bed-rock is granite. The sinking on to the main lead will be 200 to 300 ft. through basaltic rock, which occurs in 3 or more layers with intervening thin beds of clay, gravel, and scoriæ.

3. The Main Cathcart lead is in the valley of Deenicull Creek, and under the basaltic flow S. of the Burrumbeep station, along the river Hopkins to Jackson's Creek. The Cathcart having been joined by the Phillips' Flat and Nil Desperandum leads, meet probably at, or S. of, the Burrumbeep station. From here, the lead bears apparently to a point some 20 chains E. of the confluence of Jackson's Creek and the Hopkins, and thence S. towards a grand junction with the Main Hopkins. The sinking on the upper portion of this lead is through 65 to 150 ft. of clay and intermixed clay and gravel; on the lower course, through perhaps not less than 150 to 300 ft. of basaltic rock.

4. In the Concongella lead, in the valley of the like-named creek, from Armstrong's to and past the township of Great Western, the strata to be sunk through are alluvial silt resulting from the operation of creeks, and clay and gravel beds 50 to 100 ft. thick resting on granite bed-rock.

5. The granite country lying S.W. and W. of the township of Great Western, between Concongella Creek and the S. spur of the Black Range, and containing the Pliocene drainage deposits from Jonathan Gully and numerous other leads, has received but scanty attention from the miner. The sinking is through granitic detritus, local drift, and clay and gravel beds varying from 20 to 50 ft. in depth, but deepening N. towards the Concongella lead.

6. The Great Western elevated plateau N. and E. of the existing gold-workings is composed of Older Pliocene gravel-drift resting upon decomposed granite. The lead itself has been worked for a length of 2 miles, and a width which exceeds in places 1200 ft. From the alternate dryness and accumulation of saline waters, and the undulations, both longitudinally and laterally, of the bed-rock, it seems conclusive that the "lead" is simply a depression in a former sea bottom. Similar depressions, filled, no doubt, with auriferous gravels, occur probably again in other places under the plateau, which extends N. towards the Wimmera river, and offers a highly promising field to the prospector. The gold in the Great Western lead, as in the older drifts generally, occurs in fine scales; pieces weighing 1 dwt. are rare, and the largest "nugget" obtained hardly exceeded 5 dwt. With the exception of the Great Western, which is variably wet and dry, all the leads enumerated are more or less heavily charged with drift water, and demand superior skill, appliances, and capital for their proper working.

The number of quartz lodes in the Ararat division that have been mined upon at various times is 23. But of these, many have long since been abandoned, and respecting them no information could be obtained, owing to the state of inaccessibility of the deserted shafts and workings.

1. Mitchell's reef is a vein 6 to 10 in. thick; in places, the walls of the lode bulge out to a width of 24 in., and the lode-stuff then occurs in thin bands encasing strings and riders of slate rock. The whole material is removed for crushing, and the miners speak of the reef being 2 ft. wide, which is, of course, not strictly correct, more particularly as the gold seldom enters into the slate here. The greatest persistency, both in thickness and yield, is at the depth of 40 to 60 ft. Elsewhere the gold occurs unevenly, generally very sparingly distributed, or it occupies nests, from which now and then some rich specimens were removed, that led to the sinking of a disproportionately large number of shafts; but the highest yield obtained has in no crushing exceeded 15 dwt. per ton. The greatest depth to which the reef has been worked does not reach to

the level of the "alluvial" leads in the neighbourhood. Setting aside the disadvantage arising from an undue amount of dead labour which has to be expended in the working of all small veins, it may fairly be questioned —not only in this instance, but with regard to several other reefs in this district similarly situated—whether the workings should not be carried down at once to a depth below that of the leads within the immediate drainage area, in order to ascertain the character of the stone in country that has not been affected by the receding of mineral waters during Newer Tertiary times. About $1\frac{1}{2}$ mile S. of the prospecting shaft, the lode is again visible on the surface, and is being worked under the name of Port Fairy Gap reef. Here the stone yields 12 dwt. per ton, at a depth of 30 ft. from the surface.

2. Moore's reef is a collective name given to a series of quartz veins which traverse the low hilly country $2\frac{1}{2}$ miles N.E. of Ararat. The workings in claim No. 3 S. show, on a width of 48 in., 3 veins of 5, 9, and 8 in. respectively, separated by soft slate rock, which is again interstratified by numerous auriferous quartz bands. The entire thickness (4 ft.) of stone is being treated under the crushing-mill. There are many other quartz veins in this mine, but no indication of gold in them has been observed. In claim No. 1 N. 2 groups of veins have been worked upon. The W. group consists of 4 veins, 2 to 8 in. thick, which unite into a tolerably homogeneous lode 22 in. thick at 72 ft. from the surface. It has proved persistent down to the water-level at 120 ft., at which depth work was suspended. The stone has yielded 7 dwt. to the ton. The E. group is represented by 3 veins of 8, 7, and 18 in., separated respectively by 9 in. and 6 ft. of slate. The eastmost vein crops out on the surface, and has yielded in one place 2 oz. 16 dwt. of gold per ton of quartz. At a distance of 30 ft. S. of where the section is taken, the entire thickness of 8 ft. is occupied by innumerable veins and bands of quartz, and has been wholly removed for crushing. The enclosed slate bands proved highly auriferous on being washed in the dish. The greatest depth reached on Moore's reef is that of the Noah's Ark shaft, which was sunk to 200 ft., without, however, striking the veins. It was subsequently connected on the E. with the 80-ft. level of an abandoned shaft, from which the E. group of reefs was then worked.

3. New Year's reef is a well-defined lode lying about 48 chains W. of Moore's. A single shaft has been sunk. At 25 ft. from the surface, some promising specimens of gold were obtained both from the quartz and slate casings ; but at 40 ft. not a colour was visible, and, without any trial crushing being made, the shaft was abandoned. The quartz, being vitreous, shows a marked difference in appearance from the opaque stone of Moore's and other veins in this locality.

4. Pioneer reef lies still farther W. in the same locality as the two

last-mentioned reefs, and presents an accumulation of veins similar to that at Moore's. In the prospecting claim, 4 veins, 30, 7, 22, and 24 in. thick respectively, were worked at a depth of 170 ft. In a shaft some short distance S. of the prospector's, these 4 veins split up into a network of branches, and form, with the included slate bands, a broad "mullock reef" 7 ft. thick. Other irregular deviations from parallelism in the walls of the lode are said to occur in different parts on this line of reef; but the workings whereby such features are stated to have been disclosed are no longer accessible to examination.

5. Golden Hope reef is situate at the head of California Gully. Two prospecting shafts have been sunk on this reef, which runs in massive slate country. A trial crushing of 20 tons of stone gave an average yield of 3½ dwt. of gold per ton. The quartz is rich in cubical pyrites, and below the water-level this mineral becomes very abundant, both in the quartz and the slate. A small parcel of this pyrites has been treated, yielding at the rate of upwards of 13 oz. to the ton. The outcrops of 2 other quartz veins are visible within a distance of 90 ft. W. of the Golden Hope; but nothing has been done in the way of ascertaining their mining value.

6. Bourke's reef, at Port Curtis, is a flat vein, 6 to 14 in. thick, cutting through granite. It has yielded some exceedingly rich stone, and has been worked to the water-level at 78 ft. The low angle under which the vein dips requires it to be worked like a seam, although the nature of the hanging-wall renders this mode of working very unsafe and costly. With the increasing depth, the rock becomes harder, the stone poorer, and the vein less regular, splitting up into several branches. Morgan's, Amalia, and Honeysuckle reefs, in the same locality, are similar thin veins in granite, and where the rock is disintegrated the stone yielded as high as 6 oz. of gold to the ton. The Silurian rock along the granite boundary at Port Curtis is only altered for a limited distance, nowhere, apparently, exceeding 20 or 30 yd. Outside that girdle, the ordinary blue and yellowish-grey clay-slates prevail. It is probable that the jutting portion of granite at Port Curtis is merely completely altered schist, as the grey, granular ternary granite typical of the Lexington area is not met with for 40 or 50 chains from the W. boundary of the stratified rocks at Wattle Gully.

7. Rhymney reef offers, up to the present period of mining, the sole instance of a "cross reef" in this division. It is a lode 18 in. wide, bearing W. 30° S. across the strike of the bordering rock, and dips N. at 80°. It has been worked to a depth of 240 ft. The "run" of gold occupies a zone 20 to 40 ft. in width, and was first met with on the cap of the reef close to the working shaft of the Rhymney Co., whence it shoots rapidly W. Outside this zone, the lode contains little or no gold. The

reef has been cut in several pits E. of the working shaft, but it proved to be barren, and beyond a distance of 200 ft. was altogether lost. The highest yield of gold obtained was $2\frac{1}{4}$ oz. per ton. From the discovery of the reef in 1870, till the permanent cessation of work in 1874, the quantity of quartz raised from this lode amounted to 1963 tons, the proceeds of which were 1440 oz. of gold.

8. Eaglehawk is a reef 18 in. to $3\frac{1}{2}$ ft. thick, dips W. at 64°, and has been worked to a depth of 240 ft. The average yield of gold has been $4\frac{1}{2}$ dwt. per ton. Below the water-level at 115 ft., both the lode-stuff and the encasing blue slate rock are heavily impregnated with iron-pyrites. A laboratory treatment of 6 lb. of pyrites resulted in the yield of 2 dwt. of gold.

9. Campbell's reef, Moyston, is a lode in metamorphic schist, 7 to 15 in. thick, dipping E. 12° N. at 75° to W. 24° S. at 85°. From the discovery of the reef in September 1857, to the last crushing in May 1875, it is estimated that 106,000 tons of quartz, yielding 76,000 oz. of gold, were raised from this lode. In the Kangaroo Co.'s mine, the reef dipped regularly at 79° E. within well-defined walls to a depth of 480 ft. At this level, the lode became pinched, and at 540 ft. the stone died out, although the smooth backs were still clearly defined, and (the "track of the reef") persistently followed on by the miners. At 230 ft. from the surface, a cross-cut was driven W. for 148 ft., but discontinued on account of the extreme density of the crystalline schists. The quartz in this mine yielded 2 oz. 2 dwt. per ton at 250 ft.; 1 oz. at 400 ft.; and only 5 dwt. at 510 ft. In Morgan's claim, the yield was—at 250 ft., 2 oz. 12 dwt.; at 450 ft., 16 dwt.; and at 510 ft., $6\frac{1}{2}$ dwt. per ton. In the Invincible Co.'s mine, the lode averages 10 in. thick, and dips 80° E. to a depth of 400 ft., where it changes to 84° W. The best payable quartz was got from a "shoot" about 150 ft. wide, dipping N. At the lower level, the stone within the shoot yielded 13 dwt. per ton, while the quartz raised from outside the auriferous belt scarcely paid the cost of mining and crushing. The Perseverance Co. crushed stone from their 400-ft. level which averaged 2 oz. 3 dwt. a ton; the Extended Southern Cross Co., from a depth of 580 ft., 4 dwt. 21 gr. per ton; and the North Star Co., in one of the most N. shafts on this line of reef, obtained but 3 dwt. 5 gr. per ton. The run of gold evidently shoots N., and, supposing it to be persistent, would be met with in the N. claims at considerably lower depths than have been reached by any shafts in this locality.

10. About 50 chains S. of the original prospecting claim on Campbell's reef, and approximately corresponding with the extended strike of the latter, is a lode worked by the Sir George Bowen Co., 6 to 15 in. thick. It splits up into various branches in the 190-ft. level. The shaft of this company is sunk in an elvan dyke (quartz porphyry), the thickness of

which has not yet been ascertained. At the place where the branching off of the vein occurs, the elvanite is closely studded with cubic pyrites, and the quartz leaders streaked with veins of galena. The character of the country is quite different from that of the N. claims, and it seems all but certain that the lode in this mine is distinct from Campbell's. The proper mode of exploring this mine would be to ascertain by E. and W. cross-cuts the extent of the dyke laterally, and the nature of the country adjoining.

11. The Silurian ranges at the sources of the Six-mile Creek, in the parish of Bulgana, are traversed by numerous quartz reefs, none of which has hitherto been tested. The apparent absence of faults or splits, the great thickness of some of these reefs, and the persistence and regularity of their strike, distinguish this country from that in which the lodes of the Ararat gold-field proper have been thus far worked. This area recommends itself as a favourable field for lode prospecting.

Ballarat.—From R. A. F. Murray's report on the geology and mineral resources of Ballarat, dated Mar. 29, 1873, the following valuable information is derived.

Tertiary Gold-drifts.—Under the term "drift," are here included all detrital deposits of clay, sand, and gravel, water-worn or angular, loose or cemented. In naming the Tertiary gold-drifts, their nomenclature, according to European classification, has been deferred until more extended research shall have brought to light evidence as to the precise periods to which they are referable. There are 4 clearly defined epochs of gold-drift in the Ballarat district, whose relative local positions have been indicated by the names "oldest," "older," "recent," and "most recent," referring to the periods rather than to the drifts themselves. The "oldest" period included the deposit of drifts clearly antecedent to the time at which the lead-channels were eroded to their present depth. The "older" period embraced the deep-lead drifts, those intervening between the lava-flows and the lava-flows themselves, the uppermost lava-flow closing the period. Deposits of "recent" age are those that were deposited immediately after the uppermost lava-flow or "first rock." "Most recent" drifts are those in recently eroded gullies, or such deposits of clay, sand, and gravel as have accumulated subsequently to the "recent" period.

The term "oldest," as applied to the period to which certain drifts more ancient than the deep-lead drifts are referable, is here used relatively, and does not imply necessarily the absence of auriferous drifts of greater antiquity in other localities. Lithologically the principal forms are as follows:—(1) Loose quartz gravel, with well and partially rounded pebbles and boulders; (2) water-worn and angular gravel and sand, more or less cemented with ferruginous and siliceous matter; (3) sandy ironstone, with occasional layers and patches of quartz gravel ; (4) hard siliceous rock, sometimes pure and sometimes enclosing angular or water-worn quartz fragments. These forms frequently blend with one another. Rolled fragments of other rock than quartz are very rare, and the least water-worn pebbles are met with at the more elevated points or margins of terraces where the drift occurs. The first two forms prevail near Ballarat : isolated patches cap various points of considerable, but not the highest, elevation, on either side of the Leigh valley, as on parts of the Warrenheip range to the E., and various points near Napoleon on the W. These patches occur neither on the highest points nor on the lowest spurs of the Silurian ranges, but on those of medium elevation.

The northernmost and most elevated appearance of this drift is on the Warrenheip range, outside the E. borough boundary, at an altitude above sea-level of 1750 ft. The least-elevated exposed points on which these vestiges remain are those nearest to the main line of depression, as at Golden Point, Pennyweight Hill, Clayton's Hill, Slaughterhouse Hill, near Buninyong, and the Hard Hills, near Scotchman's. In these localities the gravel is very coarse, and immense rounded boulders of quartz are frequent. Some of the extensive "reef-washes" beneath the basalt are of similar character, and are probably of this epoch. Patches occur as terraces on either side down the Leigh valley, S. from Buninyong and on the fall towards Williamson's Creek. It is traceable as passing beneath the Mount Mercer lava-flow along the N. boundary of the latter, and in the natural section on the banks of the Leigh river to within a few miles of Shelford. With the fall of the country, the deposit becomes more extensive, and forms plateaux on either side of the Leigh river near its junction with Williamson's Creek, passing beneath the basalt E. of the latter. It caps the ranges, or is traceable beneath the basalt, from the Leigh river to Meredith, and thence to the ranges around Steiglitz. Plateaux of this deposit exist as far E. as Stony Creek reservoir, and it is probably traceable still farther towards Bacchus Marsh. The third form is most common in these S. localities, and the pebbles are highly water-worn. The hard siliceous rock described as one of the forms assumed by this drift is of great scientific interest, as the solution of its origin will throw light on that of the gravelly beds.

It is met with in detached outliers and small plateaux on the ranges falling towards Williamson's Creek from the W. ; it is sometimes pure, but more frequently contains imbedded quartz pebbles, and is associated with or passes into ferruginous, sandy, and cement layers. Rock of similar character, but pure, occurs in thick beds associated with the marine Miocene strata and older basalt of the Moorabool and Sutherland's Creek, near Maude ; also between Steiglitz and Morrison's and between Meredith and Elaine. Whether these various beds are of the same geological age is unknown; their similarity in lithological character is striking. No fossils have yet been found in the siliceous beds, except occasional imperfect fragments of stems, valueless as palæontological evidence. Wilkinson traced a course of drift in the form of a wide shallow lead from near Steiglitz to and under the marine Miocene beds exposed in natural section on the W. bank of the Moorabool river above Maude. He was of opinion that this drift was older than the widespread layers here referred to as "oldest," and classified the former as Miocene, the latter as Older Pliocene. Their exact relations, however, are not fully worked out, and they may eventually prove to be of the same age, the drift traced by Wilkinson simply occupying a somewhat deeper depression in the Silurian rocks than the adjacent beds. Were this established, the "oldest" could be justifiably classed as Miocene.

Dissimilarity in lithological character and unequal degrees of elevation above sea-level are not infallible evidence that drifts are of different epochs. Deposits now in actual progress occupy all elevations, from the sea to the highest mountain slopes, and vary in lithological character with their parent rocks; but their identity in geological age is indisputable. This has to be kept in view while examining the Tertiaries, especially those not of a decidedly marine character. To arrive at any justifiable conclusions as to the respective ages of the drifts; the siliceous deposits, and the Miocene beds, it would be necessary to investigate closely the connection between the beds from Steiglitz to the Moorabool, near Maude, and the relationship between the Steiglitz drifts, the Bacchus Marsh Tertiaries, and the deep-lying deposits of Lal-lal and Morrison's. The drift traced by Wilkinson was the "non-auriferous Miocene gravel" described in Selwyn's work on the physical geography and geology of Victoria. It was set down as non-auriferous on the ground that no gold was found in the few shafts and tunnels worked by the Geological Survey party. Murray, then an assistant in the party, sank one of the shafts personally, and *did* obtain the "colour." The same amount of work, with the same result, might be done on any gold-field within a few feet of rich ground. The oldest drift near Ballarat barely yields the "colour" in some places, while in others it is richly auriferous. These differences are owing to causes treated of subsequently under the head of Gold-workings (p. 664).

Taking into consideration the modes in which the oldest drift occurs, there is good reason to infer that, towards the close of the period, a valley had been eroded corresponding in outline to that now traversed by the Yarrowee; that the drift spread almost uninterruptedly from the Warrenheip range to Pennyweight and Clayton's hills, and Golden Point, then the bed of the depression, probably capping a portion of the Whitehorse Range at the head of Canadian, where occasional rounded pebbles occur in the workings ; that it overspread the area now traversed by the deep leads from Ballarat S. to Scotchman's, Napoleon, and Buninyong, thence down the valley to near Shelford ; that the spread of the drift was wide but shallow down to Buninyong, thence to Hardie's Hill comparatively narrow, but, farther S., extending over a vast area ; that it also overlaid a wide tract W. and N. from Ballarat, though no exposed vestiges are now identifiable. Marine action on gradually rising land appears to have been the principal force which disintegrated, rounded, and deposited the fragments composing the drift. As the land rose, already existing depressions—due to the softer nature of a portion of the underlying Silurian—would become deeper and more defined ; the scour in these depressions would increase, and, consequently, the drift would be heavier in their beds, as at Golden Point and other places. No remains of wood appear to have been met with in the gold-workings in this drift, either in the exposed portions, or in such sub-basaltic "reef-washes" as are referable to the same period. The character of the drift is such as would render the preservation of shells or other remains of marine fauna almost an impossibility. The powerful nature of the denuding forces is evidenced by the absence of any large fragments other than quartz, and the quantity of this shows how greatly the Silurian hills must have been denuded below their original height. The theory of marine action is, therefore, based upon the physical conditions under which the drift occurs, and which certainly indicate marine rather than fluviatile agency.

Under the term "older," are here included the gutter-drifts, the volcanic lava-flows, and the drift-deposits intervening between the latter. It is evident, therefore, that this period might be subdivided into a number of epochs, each bounded by a lava-flow, but it is preferable, in the present instance, to include them all as a group under one denomination. The lowest of the series is the gutter-drift of the deep leads. It occupies well-defined channels in the Silurian bed-rock, more or less tortuous in their course, with a steady fall towards the seaboard. The drift in contact with the Silurian is generally the heaviest, and consists principally of fragments of quartz, and the more durable varieties of slate and sandstone, intermixed with sand and clay ; rolled fragments of hard cement, probably derived from the "oldest," are also met with. Most of the quartz and other fragments are water-worn, while some are but partly so, or angular. In some places, beds of sand and clay overlie the gravel ; in others, the basaltic rock is in immediate contact with it. Numerous remains of vegetation occur in the gutter-drift. Large trunks of trees, branches, and fragments of wood, and in some instances trees *in situ*, their roots imbedded in the ancient soil, and their upper portion enveloped in lava, are met with in the gold-workings.

The older drift rarely occurs as a surface-deposit, being generally covered by lava or recent accumulations. Next to the gutter-wash comes the "fourth rock" of the miners, really the first lava-flow, which took its course along the principal lead-valleys, extending a short distance up some of the tributaries. It is confined to the deepest ground, of which it is a sure indication. As far as can be ascertained, the "fourth rock" does not extend farther up the Golden Point lead than the Koh-i-noor Co.'s No. 2 shaft. It overlies the tributary gutters W. worked by the Saints and Winter's Freehold companies, and has been proved by bores to exist in the North Park claim W. from Wendouree, on the supposed continuation of the Inkerman lead; it is also mentioned as having been struck in the Great North-west shaft. S. from Sebastopol, it appears to maintain its position as the lowest basaltic stratum as far as the Main Trunk lead has been worked, though, as will presently be shown, it becomes the third instead of the fourth "rock." On this basaltic layer are various deposits of clay, sand, and gravel, separating it from the "third rock," or second lava-flow.

Experienced miners say that the intervening deposits, though frequently thin, are nevertheless distinct, sometimes in the form of an ancient surface soil with remains of vegetation, sometimes consisting of clays, sand, or gravel. The "third rock," or second lava-flow, occurs similarly to the last described, but spreads more widely. Still, being confined between the high Silurian banks on either side of the gutters, it does not appear to have been sunk through on the Golden Point lead farther up than the Koh-i-noor No. 2 shaft; but it probably extends considerably farther up the lead than that point, having been escaped by shafts that bottomed at some distance from the lead. This, like the "fourth rock," is overlaid by varying thicknesses of clay and drift.

The "second rock" or third lava-flow underlies nearly all the W. plateau, extending over the Gravel Pits lead beyond the present limits of the uppermost flow. It has been struck N. of Mount Rowan in the Rodney shaft, and in a bore at Dowling Forest racecourse over a third and fourth layer of the same description. The "second rock" is overlaid principally by clays, which separate it from the "first rock" or uppermost lava-flow. This latter is the surface rock of the W. plateau from Ballarat westward and northward. Southward it does not appear to have extended farther than Winter's Creek near the Bonshaw shaft. The reasons for this assumption are that, while 4 distinct layers of "rock" or basalt occur in the Prince of Wales claim over the gutter, only 3 are met with in the Bonshaw. The surface fall from the Prince of Wales to the Bonshaw is 71 ft., about the average thickness of the "first rock." From the Bonshaw downwards along the lead, only 3 basaltic layers occur, and it therefore seems probable that the first, second, and third "rocks" in the Bonshaw and claims S. thereof are the second, third, and fourth of the Sebastopol plateau.

Many of the principal gullies trending from the main divide and its spurs contain the true gutter-drift in the beds of their channels, overlaid by recent accumulations. These were evidently eroded during, if not previous to, the "older" period; and indeed it may safely be assumed that the physical features of the country at the close of the period differed little from what they are now, as regards the portions that are unaltered by the lava-flows. The physical character of the deep leads and the remains of vegetation found in them, especially the occurrence of trees *in situ*, are good evidence that before the first lava-flow the country had risen above the reach of marine action. Referring to the theory of marine action on rising land, advanced as the operative force in forming the "oldest" drift, it would appear that, with the rise of the land above sea-level, fluviatile began to take the place of marine action. If, as is assumed, the rise was gradual, the latter agency, in its retreat, did a portion of the work of denuding the "oldest" drift, and wore out deeper channels in the Silurian. As river action came into play, the main valleys were cut deeper, into more tortuous courses, and acquired new tributaries. The oldest drift was removed from all but a few points, and either carried away or re-deposited in the gutters or on their banks.

The lava-flows exerted an important influence on the physical and geological features of the country. Each successive layer formed a sort of dam, behind which were accumulated thick deposits of clay, sand, and drift. The flow of water over the surface of the basalt caused the deposits on it of clay, sand, &c., and in some places cut fresh channels, usually along its line of contact with the Silurian. In this way, some of the "reef-washes" above the level of the third and fourth "rocks" appear to have been formed. On the Eureka lead, a layer of black clay over the gutter commenced near the junction of Ashe's lead; at junction of Red Hill lead, and thence to Gum-tree Flat, 2 layers; thence to Red Streak lead, 3 layers of black clay were met with, until basalt took the place of the upper layer. These appear to have been the surface soils at periods immediately following the 3 lower basaltic flows. The uppermost lava-flow formed a strong dam across the valley traversed by the Eureka, Canadian, and Gravel Pits leads, and that area was probably for some time a lake, until an outlet was cut by the overflowing waters, which gradually eroded the existing course of the Yarrowee.

The mode of deposit of the "recent" clays and gravels (subsequent to the uppermost lava-flow) appears to have been analogous to that of the intercalated layers between the fourth and third, third and second, and second and first "rocks," the result of the temporary damming back caused by the lava. The force of the water-currents being retarded, their beds were filled up, nearly to the surface-level of the basalt, with detritus brought down from the neighbouring hills, covering the "older" clays and gravels. Denudation continued the removal of "oldest" and "older" deposits from the higher lands, and re-distributed them in the valleys. The lithological character of the beds supports the theory advanced as to their origin. Clays, sandy deposits, angular drift, and occasionally rounded gravels (the last where "older" and "oldest" have been re-distributed), showing little sign of stratification, but intermixed and irregularly deposited beneath a general covering of clay, form tolerably level flats, such as that from Ballarat towards Brown Hill, traversed by the Eureka and Caledonia leads, and the Deadhorse flat, extending from the New Cemetery to Mount Rowan. The capping of gravel and clay on the brow of the hill at the Ballarat Post Office is of the "recent" period, and is evidently the vestige of a continuous deposit connected with the beds on the other side of the Yarrowee. The close of this period witnessed the erosion of the Yarrowee channel at Ballarat to nearly its present depth, the drainage-line following the contact of the Silurian and the uppermost lava-flow: a few patches of the latter have been left on the E. side of the river, near Ballarat and Sebastopol. Thence S. the course of the river is sometimes entirely through basalt, sometimes along the line of contact with the Silurian on either side.

The "most recent" drift consists of loam, clay, and gravel, and occupies the beds of recently eroded gullies, or forms coverings over "oldest," "older," and "recent" deposits, from the denudation of which it is principally derived.

Gold-workings.—The surface workings are usually on the slopes of hills and spurs; the gold is sometimes in the few inches of surface soil and angular rubble overlying the Silurian on or near auriferous quartz veins, as at the Black Hill, Whitehorse Hill, &c. In other places, a few scattered rounded quartz pebbles show that "oldest" or "older" drift once rested on the Silurian, and was removed by denudation, the accompanying gold, from its superior weight, remaining in the crevices of the bed-rock. Surfacing is sometimes worked on a "false bottom" of clay covering deeper deposits of auriferous drift; this also occurs most frequently in close proximity to quartz veins. At Kitty's, near Napoleon, tolerably large nuggets have been found in clay several feet above the "true bottom." The thicker deposits at the foot of the hills and in the gullies intersected by auriferous lines of reef are frequently gold-bearing from surface to bottom, owing to the proximity of the matrix. It is stated that at Rotten Gully, near the Band of Hope reef, Little Bendigo, where the sinking is about 70 ft., 40 ft. was payable.

The drifts in the upper portions of gullies are usually of "recent" or "most recent" age ; as they expand into flats, the sinking becomes deeper, and the lead-drift of the "older" period occupies their ancient beds. In working these leads in wide flats, tributaries have frequently been found of which no surface indications existed. Thus the Caledonia and other leads joining the Eureka in the extensive flat of Ballarat East were discovered from the underground workings of the latter. Occasional instances occur in which the head of an "older" lead is above the level of the gully into which it subsequently trends. As the leads are followed down, they become deeper, and pass beneath the various basaltic layers.

"Reef-washes" are deposits of drift above the level of the gutters, and are of several kinds and geological ages, of which the following are the principal:—(1) "Oldest" drift *in situ*, as the Webster-street Freehold "reef-wash" and that S. of the Inkerman lead ; (2) the slopes towards the leads covered with débris from the oldest, deposited during the erosion of the gutters ; (3) the ancient soil on sub-basaltic Silurian slopes and hills, where quartz reefs occur analogous to the surface workings of Whitehorse Hill, &c. ; (4) deposits subsequent to the different lava-flows, usually along their line of contact with the Silurian, from the denudation of which, with its overlying drifts, their material is derived. These occasionally overlie the basaltic layers, but do not appear to have been found remunerative when in that position.

Leads.—A map of the Ballarat leads at once suggests their true character, viz. an ancient system of rivers corresponding approximately to existing drainage courses. There are 3 great lead systems near Ballarat: the Southern, corresponding to the Yarrowee, the Western to the Burrumbeet, and the Eastern to the Moorabool watersheds.

The Southern is the Golden Point system, the main trunk of which is formed at Ballarat by the junction of the United Gravel Pits, Eureka, Caledonian, Canadian, and other leads with the small tributary from Golden Point, whence the main lead takes its name. This lead, fed by its tributaries, the Nightingale, Malakoff, and Redan leads, has a generally S. course to near the Band and Albion Consols shaft. From this point, a lead has been worked W. to Winter's Freehold. The S. course of the lead winds through Sebastopol, the Bonshaw paddock, and Cambrian Hill, W. of but parallel with the Yarrowee. Several unnamed tributaries join from the W., and from the E. it receives the Woolshed, Frenchman's, Cobbler's, Crawfish, Black, and Suffolk leads, all of which have several minor tributaries. Near the Leviathan No. 2 shaft, at Rosse's Creek, the Napoleon lead joins from the S., and the main lead, crossing the Yarrowee several times, winds S.E. to the S.W. portion of the Buninyong Estate, where it receives the combination of Scotchman's and the Buninyong leads from the N.E., and Kitty's and the Durham from the W. Thence it is known as the Durham lead; and follows the Yarrowee valley, receiving a few more tributaries to a point N.E. from Mount Mercer, where it turns to the S.W. beneath extensive basaltic plains, under which its precise course is unknown, the Yarrowee holding an independent course S.

The question whether the Southern lead just described, or the Western lead worked from the Band and Albion Company's No. 3 shaft, is the main outlet of the Golden Point lead, is, in the opinion of many, still unsolved. Some high mining authorities maintain that the Western lead is the main outlet, and the Southern only a bye-wash of the Golden Point lead. Others consider that the Southern is the main course, and the Western a tributary to it. The reasons for the Western theory are, the deepening of the Western lead towards Winter's Freehold, and the insignificance, compared with it, of the Southern lead until the latter is augmented by the Woolshed gutter. The geological reason for adherence to the Southern theory is that, as already shown, a valley to the S. was formed during the "oldest" period, long anterior to the erosion of the leads; and whatever minor deviations may have taken place, the main drainage course would not leave so marked a depression. In reply to the arguments for the Western outlet, it is advanced that, as has been already shown, the leads were rivers, and as such assuredly varied with respect to the depth and width of gravel in their beds, precisely as existing rivers do. As regards the fall W., stated to be 12 ft. from No. 3 shaft to Winter's Freehold boundary, this cannot be taken alone as evidence, without ascertaining the continuity of the fall. Existing rivers with rocky beds frequently have reaches of which the upper end is deeper than the lower. Such a reach, filled with gravel, appears to have existed at the point referred to. With the exception of the leads being worked in Winter's Freehold, those at the Buninyong Estate, and a few other tributaries, the Golden Point system of leads is practically worked out down to Hardie's Hill, and has been partially worked, with varying results, for several miles farther. Extensive areas of reef-wash still remain, and will afford remunerative employment for a long time to come. The basalt extending W. from the Emperor shaft probably overlies a lead.

The Western system of leads has only been partially explored, and is looked to as the future hope of Ballarat in alluvial mining. The heads of a number of leads trending from the main divide W. have been more or less profitably worked. The Sulky lead heads from the Whitehorse reef near Green Leek Gully, and has a N. course, at first along the side of a range, where there is no surface trace of its existence; thence down the Sulky Gully to the Creswick road, receiving several tributaries. At the Creswick road, it crosses the main divide, and trends towards the N.

of Mount Pisgah; but the results where last worked do not seem to have encouraged further exploration. From the surface at its head, it speedily deepens to 70 ft. on the slope of the range. At the Creswick road, the depth is about 100 ft., and it passes beneath the basalt N.W. from the main divide.

The Britannia lead occupies a gully heading from very near the Sulky lead, and from a depth of 10 ft. reaches that of 90 ft. at the Creswick road, where basalt begins to overlie the gutter. The Roxburgh Castle Co. sank a shaft for this lead some distance W. from the road. At a depth of 165 ft., a drive S.W., at a distance of 600 or 700 ft. from the shaft, with a rise of about 3 ft., had wash under foot, as proved by blind shaft, to a depth of 14 ft.; the colour of gold was seen, but the gutter was never reached. The deepest ground was dry; water in the rocks was heavy.

Green Leek Gully was worked to where it opened out into a flat, the depth of sinking being 20 to 40 ft. The extension of this lead was not traced; but some distance W. the Dauntless, Ophir, and Rodney Cos. worked a gutter supposed to be formed by the junction of Green Leek with other leads from neighbouring gullies. The Dauntless shaft was 140 ft. deep, through various layers of clay and drift. No basalt reported in this or the Ophir shaft, which bottomed through similar strata at a depth of 145 ft. In the Dauntless claim, the gold was for some time remunerative; but the workings were stopped on reaching a poor sandy patch. A quartz reef in the bed-rock was met with a short distance E. from the shaft. Work in the Ophir claim was stopped on losing the level in the drive. The Rodney Co. sank a shaft by the E. side of the Creswick road, through 26 ft. of surface soil and clay, 20 ft. of first rock, 4 ft. of clay; [illegible] ft. of second rock, 59 ft. of clay, drift, and wash, with a little gold; 6 ft. of "false bottom" like broken "reef," and 2 ft. of quartz gravel (wash-dirt); total, 156 ft. This claim was abandoned, owing, by all accounts, to disputes among the shareholders and tributers. A small amount of copper was found in the wash-dirt, and the water of the mine is reported to have possessed the property of magnetizing iron, as rods worked for some time in the water would possess sufficient magnetism to lift small pieces of iron. The Deadhorse lead was worked only a short distance below the junction of California, Frenchman's, and Jenkins' gullies, which form its head; it is reported to have become poor, but at present further exploration is for some distance prevented by the occupation of the land for agricultural purposes. Farther W. the lead was struck and worked by the Ballarat Extension, Rose Hill, and Northern Junction Cos. The depth of the gutter increased from 260 ft. in the first to about 300 in the last named claim. In all these, one basaltic layer only, varying from 50 to 90 ft., seems to have been passed through, the remainder of the sinking being principally clay; several tributaries join from the N. and E.; one of these, called the Northumberland lead, is being worked for by the Rose Hill Co.

The Suburban lead has only been partially traced from one shaft, E. of the Creswick road. The depth of sinking is 137 ft., with one layer of basalt; it is apparently tributary to the Deadhorse lead. With the exception of Sulky lead, which may take a N. course, all the leads just described trend W. Judging from the racecourse bore, and a W. outcrop of Silurian near Miners' Rest, the main trunk lead of the system would appear to trend from Mount Pisgah S., beneath the Clunes road and the Burrumbeet Creek, to about W. from Mount Rowan, whence it will turn S.W. towards Burrumbeet. It is needless to expatiate on the advantages that will accrue from the successful development of this system of leads. The Essex Swamp and Inkerman leads are now being prospected for. Whether these leads belong to the Western or Southern system is uncertain; their present trend indicates the former. The possibility exists that all 3 may unite, and go W. or S., or that the Inkerman lead may go S. and the others W.; this can only be proved by the working of the Pioneer claims.

The Eastern lead system is but little known, the only workings being those now abandoned at the Rich Hill and Rosser's Freehold. Vestiges of "older" drift, once a portion of these leads, are traceable on the ranges W. of the Gong-gong Creek, the bed of which is at the Rich Hill deeper than that of the drift. Two small leads, known as the Chinaman's and Spring's, pass beneath the basalt escarpment E. of the creek, and unite under the Rich Hill, a tongue of the E. plateau. The ground was partly worked by tunnels, but these proved too shallow as the lead deepened E. The deepest portion explored was 195 ft. below the level of the plateau. One thick basaltic layer was passed through in a shaft sunk to that depth. Several other small tributaries were profitably followed from the escarpment E. into Rosser's Freehold by Cane, Donelly, and Richard's parties. The dip of the leads E. was in all cases very strong. The depth of sinking was about 170 ft., through one layer of basalt and a considerable thickness of clay, sand, and drift. The yields appear to have been moderately remunerative; but from some cause the companies stopped work, and the plants were removed. There is abundant evidence that the E. plateau, extending as it does from Fellmonger's to Gordon, covers a system of leads probably superior in extent to that of the Ballarat and Sebastopol plateau. The deep ground will have a general trend down the valley of the Moorabool towards Morrison's.

The range separating the Little Bendigo from the Gong-gong Creek was once continuous with the Warrenheip range, and divided the Eastern from the Southern and Western systems. The lava-flows from Warrenheip and Wombat Hill caused a partial change in the line of drainage. The Gong-gong Creek cut its way along the margin of the basalt and, uniting with the Yarrowee, turned W. The divide between the Moorabool and Yarrowee watersheds is in that neighbourhood farther E. than that of the period before the lava-flows. The E. basaltic area is covered in many places with ferruginous deposits, apparently precipitated from water percolating the basalt.

The connection of Tertiary drifts underlying the basalt of the Eastern plateau with those of Lal-lal and Morrison's is an interesting geological problem, the solution of which depends greatly on whether mining operations are ever carried on in the area referred to. Whether profitable workings are likely to be found in this or the unexplored Southern and Western areas is next considered. The principles to be kept in view are thoroughly established and recognized. They are—(1) That the supply of alluvial gold was derived from quartz reefs, broken and disintegrated by denuding action during the various drift periods; (2) that, except in very fine particles, gold in alluvions has not travelled far from the point where it was separated from its matrix. All the Ballarat gold-workings testify to the truth of these principles. The richest ground is always in the neighbourhood of quartz reefs or veins; even in cases where successive drift-deposits have been removed and re-deposited, the gold contained in the first deposit appears merely to have dropped deeper. Any gold that has travelled seems to have done so while attached to quartz or enclosed in clay. A large proportion of the alluvial gold was probably disintegrated from its matrix during the "oldest" period; as the lead-channels were eroded, the "oldest" gravels were in a manner sluiced down, and their gold re-deposited in the river-beds, together with the fresh supply from the further disintegration of the Silurian.

The Golden Point lead traverses the line of several known gold-bearing reefs, and the quality of the lead was found to vary with its position as to these, becoming poorer when at a distance from them, and richer when again in their vicinity. It seems very improbable that, as regards coarse gold, the supply in the Golden Point lead at Sebastopol was in any way connected with the richness of the principal leads. The quality of the various "reef-washes" varies similarly. In those apparently of marine origin of the "oldest" period, the gold is more equally distributed, as might be expected from the different nature of the depositing agencies.

The occurrence of nuggets on "high reef," above the level of the gutters, simply indicates that their weight enabled them to remain in their position during the deeper erosion of the neighbouring gutter, and that their original matrix is at no great distance. The inevitable conclusion is that on the character of the quartz reefs or veins in their immediate vicinity depends that of the gravels. This appears to be the true explanation of the barren quality of some of the gravels, such as the "non-auriferous Miocene gravels" already referred to: they have simply been deposited along a line of poor quartz reefs; and were the Steiglitz gravels prospected on the line of strike of some of the known auriferous reefs, they would in all likelihood be found gold-bearing, if not remuneratively so.

The leads *following* the course of lines of auriferous quartz are more likely to maintain a continuous and equal yield than those *crossing* a number of reefs at various intervals. Gold in quartz veins frequently occurs in "shoots," alternating with barren portions; this feature also causes variations in the amount of alluvial gold. Believers in the theory of the Western outlet of the Golden Point lead appear to exaggerate the importance of its bearing on the future of Ballarat alluvial mining. That there are leads, and extensive ones, trending W., is beyond a doubt. If the quartz reefs intersected by them are gold-bearing, they will be quite as remunerative as the Golden Point lead would be if it trended W. The character of the quartz reefs is the main consideration; and a feature in connection with these requires particular notice. This is the occurrence of wide alternate auriferous and non-auriferous (or at least very poor) belts of quartz reefs, noticeable at Sandhurst, Ballarat, and other gold-fields. A great auriferous belt extends from Creswick, through Ballarat, S. to Scotchman's, Kitty's, and Buninyong. The E. boundary of this belt appears to be a little within the E. borough boundary, and is traceable with tolerable clearness N. to Slaty Creek, and S. to the E. of Buninyong. With a few breaks, owing probably to the unequal distribution of the "shoots" of gold in the reefs, all the gullies W. of this line have been profitably worked. E. of the line, most of the gullies, and many of the quartz reefs, have been prospected from Slaty Creek down to the Warrenheip range, and thence to Williamson's Creek, and in no case has more than the colour, or a few specks, been obtained. The auriferous belt appears to narrow and contain fewer "shoots" S., as only a few tributary leads, and very little shallow working, have been found on either side of the Yarrowee S. from the Garibaldi claim.

The richness of the Western and Eastern systems of leads will depend, in a great measure, upon the occurrence of barren belts. The workings at Winter's Freehold have proved auriferous drift *coming from* the W.—an auspicious indication of the existence of gold-bearing reefs in that direction, and the probable improvement of the gravels, and, in fact, a more prosperous sign than if the main outlet of the Golden Point lead was W. It is also a favourable augury as to the character of the Western leads, of which the North Park and the City of Ballarat Cos. are the Pioneer claims. Even should these fail to get payable gold, further prospecting W. is highly to be recommended, as another strike of gold-bearing reefs is likely to be intersected on a line N. from Haddon.

The depth of sinking W. is not unlikely to decrease, instead of increasing, as the surface fall is considerable. The depth of the main Southern lead at Scotchman's is about 100 ft. less than at Sebastopol, showing the fall of the lead to be less than that of the surface. The same may prove to be the case W. The extension of the main Southern lead will pass through Bell's and probably Graham's properties. In the latter property, the "oldest" drift beneath the basalt has been partially exposed by tunnelling from the W. bank of the Yarrowee. Gold was found in considerable but not quite payable quantity in numerous disconnected "runs" and hollows in the Silurian. The river-bed below has been extensively and profitably worked, and it seems likely that gold-bearing veins may exist in the locality, and that payable workings may yet be opened beneath the plains. As long as the bed of the main lead continues to be in Silurian rock intersected by auriferous quartz veins, the alluvial gold will continue. The yields from the Leigh Grand Junction claim, though poor, were not of so utterly discouraging a nature as to prohibit further enterprise, and an increase is not less probable than a diminution of yield as the lead travels S. The miner alone can ascertain the true character.

As regards the Eastern system, it is known that granite underlies a portion of the basaltic area, and may form the bed of some of the leads. Nevertheless, a large extent of Silurian country is to be expected, and, in so wide an area, the occurrence of auriferous "belts" of quartz reef is very probable. On such occurrences will depend the character of the leads. Deep ground, tributary to the Eastern system, undoubtedly exists beneath the lava-streams N.E. from the Green Hill and S.E. from Mount Buninyong. As no quartz reefs or shallow workings have yet been proved payable near these flows, the auriferous quality of their underlying drift is problematical.

Quartz reefs.—As the alluvial drifts owe their auriferous character to neighbouring quartz reefs, the quality of the former might be considered a fair indication of that of the latter. Such, at first glance, would not appear to be the case at Ballarat, where the quartz workings hitherto have been limited, compared with the alluvial, and the general average quartz yield has been far below that of other districts. That the reefs generally, so far as proved, are as a rule poor, there is no doubt, and the explanation as to the great quantity of alluvial gold is the enormous denudation to which the Silurian rocks were subjected during the "oldest" period, and the concentrating effects of subsequent agencies. The small proportion of quartz to the bulk of the Silurian schist, coupled with the predominance of the former in the gravels, indicates the incalculable quantity of quartz that has been broken into fragments and rounded into pebbles, and the still greater amount of shale, sandstone, &c., that has been reduced to silt and sand and carried away to the ancient seaboard. Were all the quartz but slightly auriferous, the amount of gold set free would necessarily be large; but it has not been uncommon to meet with very rich "shoots" and patches, as well as occasional nuggets, in the Ballarat reefs, so that many such "shoots" may have contributed to the alluvial supply.

Although in many cases the great size of the Ballarat lodes compensates for their poverty, and this branch of mining may be said to be slowly but surely progressing, it is complained that the reefs are not solid and defined like those of Sandhurst, but consist of a number of leaders and veins, and do not partake of the character of true lodes. This certainly is the case with many of the reefs at high elevations, but it also appears that they are best defined and most solid where deepest worked. In the Sovereign and Victoria claims, indications of increased permanence are met with in the deeper levels, and the shaft of the former is to be sunk to 1000 ft.

The Burra-Burra reef, below the basaltic table-land, is reported to be solid, of great size, and to give a payable average yield. The Prince of Wales Co. are working a reef upwards of 600 ft. from the surface, which, with the surface fall, would equal a depth of nearly 900 ft. at the Sovereign claim. The reef is here described as of a permanent and remunerative character. The reef worked by the Temperance Co. at Little Bendigo, is considered by many to be the only true lode near Ballarat; it certainly has a more persistent character, and gives a better general yield, than most of the reefs in the district.

The Black Hill reef is generally described as showing no characteristics of a true lode. It is composed of a number of "flat leaders," dipping E., confined between well-defined walls, underlying W. The same was the case in the upper workings on the Bird's reef, Sandhurst; but at a considerable depth, the cap of a solid lode, 35 ft. thick, was struck, and worked with highly remunerative results. The Black Hill veins may similarly develop into a permanent lode at a great depth.

If quartz reefs are of subterranean origin, their general increase in size and richness downwards is highly probable. The reefs of Sandhurst are at surface about the level of the deepest workings at Ballarat, as regards height above sea-level, and it is likely that, when the level of the Sandhurst reefs is reached in the Ballarat workings, the reefs of the latter will assume an equally permanent character with those of the former gold-field. A great tract from Slaty Creek to Scotchman's, with a width of 3 to 5 miles, is open to the quartz miner. The alluvial workings throughout have been highly productive. Special attention may be drawn to the country immediately S. from Slaty Creek ; numerous quartz reefs are exposed by the workings in the beds of rich alluvial deposits, and not a shaft appears to have been sunk to test the former. The figures given by Wood join with the natural indications in predicting a long and prosperous future for Ballarat in quartz mining on the ranges and beneath the basalt.

Until recently, no discoveries of diorite dykes have been made near Ballarat ; such dykes, sometimes of great size, traverse the Lower Silurian in many localities, and are not, as many suppose, confined to the Upper Silurian. In the Upper, they are more plentiful, and more frequently accompany or contain auriferous quartz veins. A diorite dyke has lately been struck in the Band and Albion Consols No. 4 shaft, now being sunk for a quartz reef proved in the alluvial workings. The connection between the dyke and the quartz reef is not yet established. Featherstone, when working in alluvial, drove through what appears to have been a decomposed diorite dyke ; a quartz reef parallel with the dyke traversed the bed-rock about 50 ft. W., and the wash-dirt in the vicinity was exceedingly rich. The dyke has, as far as can be seen in the shaft, a N. and S. bearing. This is worthy of note, as it may lead to valuable discoveries.

Few lava dykes like those of Sandhurst have yet been met with ; one has lately been struck in a shaft now sinking for a quartz reef at a depth of 200 ft., 140 of which is through Silurian schist. This is at the W. boundary of the Buninyong Estate.

At the Buninyong Estate Co.'s No. 8 shaft, a somewhat unusual occurrence was met with in the workings. From the shaft at a level of 270 ft., a run of wash was followed for a considerable distance S.W. until the fall of the wash caused loss of level ; the bed-rock was the usual Silurian slate and shale. From a depth in the shaft of 340 ft., a drive was put in W. 423 ft., and a S. level was driven thence to meet the continuation of the wash. This drive at 410 ft. suddenly entered a mixed mass of clay, angular fragments of Silurian, from a small size up to several feet in diameter, angular quartz, and immense blocks of exceedingly hard dense lava, piled on one another or isolated throughout the mass. Some of the Silurian fragments were reddish in colour, as if exposed on the surface ; others were in character like the rock met with in very deep workings. A few isolated nests of quartz gravel were encountered, and a layer of basalt resembling a flow was passed through, and dipped under foot S. ; beyond it, the same stuff continued, but with more numerous blocks of lava. Silurian was again struck at 960 ft. from the W. drive. At 460 ft. in the S. drive, another drive W. passed through 150 ft. of the material described into a mass of broken Silurian rubble, containing much water where the drive ceased. A blind shaft was sunk 40 ft. in the S. drive without change. Similar material occurs on the surface by the dam, and thence S. across the road; it has every appearance of being a volcanic outlet-pipe.

Beechworth.—The following observations on the deep leads of the Ovens district are taken from some notes by A. W. Howitt.

The alluvial gold worked in the Beechworth district has been derived from the Silurian strata, and not from the granites. The area of Murray Tertiaries, in which the Ovens and Murray rivers flow and ultimately join, and into which the deep leads have been traced, was probably once a hill country, sculptured by streams in highly inclined strata of Silurian age. Including the whole of the area embraced within the Silurian hills bounding the confluence of the Ovens and Murray rivers, there cannot be less than 500 sq. miles of country which has thus been subject to denudation and erosion, and in which as yet no gold-workings have been sought for. It is quite a legitimate inference that whatever gold was contained in those strata has been deposited somewhere within that area, and in all probability in the drift-deposits of former streams. Were it possible for gold to travel any distance in a horizontal direction under the ordinary denuding and eroding agencies of nature, then it would not be possible for man to retain it with the apparatus such as the sluices and boxes which he employs. Many of the operations practised for purposes of mining, are only those used on a gigantic scale by nature. We are now, as it were, but washing up huge natural ground-sluices, and the Tertiary beds of the Murray and Ovens valleys may be likened to an immense tailing-dam, under which other ground-sluices probably are hidden.

It is of course not possible to point out where, underneath the overlying deposits, the ancient water-courses (deep leads) may be situated. There are no sufficient data, nor can any one at present say whether they may be found conjoined in one stream, or following separate courses, such as the Murray, the Ovens, and their confluents do now; neither can any one forecast whether the gold deposited in that area is much or little, whether it is concentrated in leads or widely spread in drifts. The proper practical investigation of this question would be by carrying out a series of borings on a carefully considered plan, for instance, commencing at the N. edge of the trough at Wahgunyah, and skirting the hills to the Springs between Chiltern and Eldorado, thence crossing to Futter's Range, W. of Wangaratta. This would reveal the contour of the bottom, the position of the deep ground, and probably furnish sufficient data as to the payable nature or otherwise of any auriferous deposits crossed. It would also give a key, not only to the entire valleys of the Murray and Ovens rivers, but also furnish valuable data in respect to other similar localities. The results viewed practically could not fail to be important: if disclosing the existence of payable auriferous leads, the area opened would be immense; if, on the contrary, the results showed that the ancient stream-beds were non-auriferous, or too poor to pay for working, then the result would be so far advantageous that it would prevent a future useless expenditure and loss of capital which might be more profitably employed elsewhere. Howitt thinks that the inferences to be drawn in respect to the area are on the whole favourable.

Gippsland [*North*]. Dargo district.—In numerous places, surrounding the escarped edge of the plateau, in the valley of the Dargo or of the Crooked River, water-worn quartz gravel has been found resting upon the older rocks, and covered by the masses fallen from the basalts. These gravels are generally auriferous to a greater or less extent, and claims have been opened for the purpose of working them. In descending from the Dargo high plains to what is called the Mayford spur, the basalts are found to fall in height in the usual steplike manner, and to cease at about 1000 ft. elevation above the Dargo river, where nearly vertical pale-coloured slates and sandstones, evidently the continuations of the auriferous series of Crooked River, reappear with the normal strike. The dip is here to W. at about 70°. For ½ mile or more along the line of contact, a considerable amount of well-rounded pebbles of quartz and sandstone covers the ground. Two claims have been opened here. Several cuts have been taken into the face of the hill, laying open the gravel beds, the underlying rock, and the overlying thick talus from the basalt sheet. The solid basalt has as yet not been reached. The total thickness of the gravels is 30 to 40 ft. They are mostly rounded vein-quartz and pale sandstone, with a few pebbles of quartz derived from the crystalline schists E. of the Dargo river. The gold is generally fine, and diffused through the gravels in amount sufficient to pay working expenses while prospecting—say at the rate of 30*s.* per man per week.

Between the Silurian bed-rock, and the auriferous quartz gravel, was found a plant-bed, and specimens of the fossils were determined by Professor McCoy as being of Miocene age, one being *Cinnamomum polymorphoides*. The plants, together with wood which is occasionally altered to lignite, are found in sandy clay, immediately overlying a sand-bed on the rock. The auriferous quartz drifts overlie the plant-bed, and show tolerably regular arrangement, such as is to be seen in eroded beds of river gravel. Here is thus an ancient river-course of Miocene times, which was covered over by a flow of basalt. Since that period, a new valley about 1000 ft. in depth has been excavated to the E. of the old river.

Outcrops of similar quartz gravels are to be met with down the course of the Dargo, in that of the Little Dargo, and in the valleys of the Crooked River sources. At the edge of the basalt sheet near Mount Table-top, denudation has completely laid bare the old channel, and the gravels have been washed and concentrated into gullies running towards the Dargo. The workings have laid bare the rim-rock for some distance, which has a course of about S. 40° W., in the supposed direction of the stream. The width of the channel is here not over 70 yd., and the bed-rock where laid bare shows it to have been rugged and uneven in the extreme. It seems somewhat difficult to imagine how the gravel can have been deposited with even that regularity which it exhibits. The bed-rock is pale-coloured slate and sandstone, dipping S.W. at about 60°. The gold found is principally on the fall inward of the rim-rock, on the right side going down stream, and is very flaky and laminated, bringing 3*l.* 19*s.* 6*d.* per oz. in Bright. During the two years ending 17th November, 1875, the yield was 154 oz. 2 dwt., but it has since fallen off. From the small width of the channel at Table-top, and the diminished body of gravel as compared with that at Mayford spur, this is probably only a branch.

The thickness of the basalt at Table-top, which may be taken as a fair average, is not less than 400 ft. On the N. side of this mountain, traces of quartz gravel are apparent, and it is not improbable that the course of the old stream may be here underneath the basalt itself. From this point for a little distance, the volcanic rock has been denuded, and the bed-rock of slates and sandstone rises in height. The basalt, recommencing (being here distinctly augitic), continues to the summit of the flat ridge separating the Dargo and Cobungra rivers.

In descending from the basalt plateau to the Lower Palæozoic rocks, quartz gravels, similar in character to those already described, are found at the contact. The appearances are similar, but on a larger scale. The quartz gravels have been much denuded and concentrated in gullies running down towards the Cobungra river, and have been worked with good results.

It seems probable that the auriferous gravels at Mayford spur, Table-top, and at Morris's, are parts of an ancient river, whose course was some thousand feet above that now followed by the existing Dargo. A section taken across the present valley at Mayford would show a profile similar to that shown by the Cobungra. If the conclusions that the present Dargo and Cobungra are the representatives of the Miocene rivers are well founded, it will follow that in both cases the valleys have shifted to the E., and now occupy the place of the former watersheds. The consideration of these Miocene rivers becomes an important one, in view of their auriferous character. Whether the gold-workings in the Cobungra and those in the Dargo form part of one and the same stream, or are parts of two distinct streams, affects this part of the question but little. It seems probable that the drainage-areas of the former rivers were essentially those of the existing rivers: and that therefore, although the Dargo has cut to the E. into the former divide, the sources of the Miocene Dargo would empty into the Dargo valley, and those of the Miocene Cobungra into the Cobungra valley. In any case, whether the drainages have been distinct, or whether the stream worked in White's claim communicated with the stream worked at Sinnott's, by way of Morris's, one fact becomes clear—that all the "leads" whatsoever must somewhere or other find their exit from under the basaltic sheets into one or other of the great existing valleys. Here is the key to future mining operations. The search for these old streams can only be properly carried out by seeking for their outlets, and working in from such points. In this view, there are no obstacles to the prospecting of these Miocene auriferous deposits by miners, beyond such as have been ordinarily overcome by them; but as to the results to be obtained, doubts may be felt. The Whites have certainly raised a considerable amount of gold from their claim at the Cobungra, but their workings have as yet been only at the surface. There exist no reasons for concluding that these ancient streams have been more richly auriferous than existing streams in North Gippsland; and it is doubtful whether in that case the labour of extracting the hard cemented quartz wash by tunnelling would be very remunerative. That wages may be made, and apparently good wages, seems probable from the data procurable. The field for prospecting is tolerably extensive, and in the existing condition of gold-mining it is such places as the Dargo high plains that must be looked to for new ground.

At Morris's claim, below Boiler Plain, the richest gold was got in the little isolated remnant of gravel first found, and the gold was here heavy and coarse; at the workings, where the tunnel advised to be driven by Brough Smyth was put in along the bed of the lead, the gold was found coarse and of a good sample on the high reef on the W. slope of the gutter. Previous to the contractors' commencing the tunnel, the Government prospecting party commenced a shaft which would probably have reached the deepest ground within 20 ft. of the surface, but on arrangements being completed to drive the tunnel to test the same ground, and on finding the tools they then had were insufficient to get through the hard cement reached at 10 ft., they desisted from further sinking. The last 6 ft. of the shaft passed through coarse heavy gravel, and in every dish tried, 20 to 50 specks of fine gold were obtained, and the last, from the cement, was of somewhat heavier character than that washed from the stuff above. The prospects since obtained by the men who drove the tunnel show a still further improvement, though not equal to the prospects reported from the higher reef; this, however, is by no means uncommon in mining experience, as it is frequent both in deep and shallow alluvial mining to find the richest deposits of gold on points and slopes of the bed-rock, as well as in the deepest portions of the bed.

Many of the creeks and gullies draining the plateaux, though patchy, have yielded good returns below where they have cut through the courses of the old gravels; the Twenty-five-mile Creek, in particular, is stated to have been best close up to the junction of the Silurian and basalt, and was worked until the number and size of the fallen blocks of the latter prevented the diggers from going farther. The general information obtained all leads to the conclusion that the gravels are auriferous throughout, but that, from their great thickness, and the dissemination of the gold through a great portion of that thickness, they can only be profitably worked on a large scale, and by means of an ample water-supply for ground-sluicing or hydraulicing. The latter method will only be available within certain limits near the exposures of the gravels on the hill-sides; for as they are worked in towards the hills, the enormous thickness of overlying clays and sands, with the basalt above, will be too much even for the Californian hose to compete with effectively. Ultimately, therefore, the working of the gravel will have to be accomplished by means of tunnels, near the entrances of which water will have to be conducted in sufficient volume to form powerful sluices, into which the wash-dirt can be tipped as brought out. Even with the short races now in use, an over-abundant supply of water is available during the wet season; but this runs short during the dry months, so that, to enable regular work to be carried on, races of great length, tapping springs and the heads of constantly running streams, would be necessary to ensure a supply during the whole year.

Subjoined is an estimate of the lengths of the portions of the main lead and its principal W. tributary which remain undenuded S. of the Cobungra, too little being known of the deposits under the basalt of the Bogong plateau to admit of their being included:—Cobungra plateau, 3 miles; Boiler Plain, 1 mile; S.W. side of Table-top, ½ mile; Mayford spur, 1½ mile; between Pyke's Creek and Little Dargo, 1 mile; W. branch from direction of Thirty-mile Creek, 5 miles—total, 12 miles. Other small leads concealed beneath the basalt might possibly increase the actual length of workable ground to 20 miles. The width and thickness of workable gravel will of course vary greatly, but may be estimated at 20 to 100 ft. for the former, and 2 to 10 ft. for the latter. Murray considers that there is good reason for the opinion that fairly remunerative, and, in places, rich yields, are likely to be obtained, but that, owing to the scarcity of quartz reefs in the adjacent country, there are no grounds for expecting that they will approach in value the returns from the leads of the western gold-fields, which are situated in country traversed by great belts of auriferous quartz reefs. Assuming the gravel included in the above estimate to afford a fair margin of profit over working expenses, there is certainly a great field open to the enterprise of the mining public.

Mitchell river.—The gold-workings are confined at present to the creeks and the older alluvions on their banks. Auriferous quartz-veins have been discovered, and are now being worked, higher up Boggy Creek. The gold found in the creek, where it flows through strata of Silurian age, has precisely the same coarse and nuggety character as that obtained from similar sites at the Crooked, Dargo, and Nicholson rivers. When the creek, however, passes from the slates and sandstone with quartz veins to the Mount Taylor porphyries, the character of the gold changes, and is laminated, scaly, and in fine dust.

It would be of the greatest interest to the geologist, and of the greatest importance to the miner, were it possible to connect the alluvial gold of Lower Boggy Creek, either with the porphyries or the overlying Upper Palæozoic grits and conglomerates, which doubtless have been derived from the waste of older sedimentary rocks bearing quartz veins. Much of the conglomerate consists of hardened slates, sandstone, and vein-quartz. To connect the gold with the porphyries would probably affect the immense area of similar rocks on the Buchan and Snowy rivers; to trace it to the Avon sandstone would equally affect a very large tract extending N. between the Mitchell and McAlister rivers, and in the S. part of which the Freestone and Maximilian Creek gold-workings are situated.

No success attended Howitt's researches as to the porphyries; and the small streams and gullies leading from Mount Taylor, Mount Lookout, and Mount Alfred are not auriferous, excepting where their lower portions come within the influence of causes which have affected the main stream; nor has any gold been yet found either in the Upper Palæozoic conglomerates, or in the gravel immediately resulting from their waste. But an examination of the distinctive characteristics and fineness of the alluvial gold found in North Gippsland, led him to entertain the belief that within certain limits the physical character of the gold and its fineness remain constant in respect to the geological formation from which it is derived. This is summed up in the subjoined tabulated form. The examples have been selected from a considerable number, so as to compare gold from similar geological formations in localities separated as widely as possible from each other. It appears to him that the following deductions may be made:—

1. From the Lower Silurians, the atomic ratio of the gold to silver varies from 22 to 1 to 6 to 1, and the gold is nuggety, laminated, ragged, and more rarely in scales.

2. From the crystalline schists of Omeo (metamorphic), the atomic ratio varies from 4 to 1 to 1 to 1, and the gold found is laminated, ragged, and in scales.

3. From some metamorphic slates and sandstones, the atomic ratio varies from 5 to 1 to 3 to 1, and the gold found is in scales and grains.

4. The more nearly the formation approaches the crystalline schists in character, the more equal the ratio of gold to silver becomes.

TABLE SHOWING FINENESS OF ALLUVIAL GOLD FROM LOCALITIES IN N. GIPPSLAND.

Number.	Gold.	Silver.	Locality.	Geological Formation of Locality, &c.	Character of Gold.
1	64·97	34·30	Swift's Creek, Omeo ..	Metamorphic; mica-schist, gneiss, granite; pierced by greenstone and felstone dykes.	Ragged and laminated.
2	86·26	13·14	Dry Gully, Omeo ..	Ditto ditto ditto ..	Ditto ditto.
3	86·93	12·57	Big River, Omeo ..	Ditto ditto ditto ..	Ditto ditto.
4	84·96	14·13	Dargo Flat, Dargo River.	Hornblendic granite, flanked by metamorphic slates and sandstones, passing on either side into Lower Silurian.	Fine, scaly, and in grains.
5	89·36	9·84	Policeman's Creek, Dargo River.		
6	91·05	8·62	Tucker Creek, Wentworth River.	Lower Silurian	Nuggety and laminated.
7	93·97	5·62	Delegete River	Ditto ditto and granite	Fine and scaly.
8	94·01	5·29	Cumbyingbar Creek, Bem River.	Ditto ditto	Nuggety and laminated.
9	95·11	4·56	Shady Creek, Tambo River.	Ditto ditto adjoining a granite area.	Ragged and laminated.
10	96·80	2·70	Good Luck Creek, Crooked River.	Ditto ditto	Nuggety and laminated.
11	97·54	2·46	Upper Boggy Creek ..	Ditto ditto	Ditto ditto.
12	94·13	5·25	Upper Boggy Creek ..	Ditto ditto	Ditto ditto.
13	94·95	4·85	Lower Boggy Creek ..	Porphyry overlaid by Upper Palæozoic shales, sandstones, and grit.	Fine laminated.
14	94·77	5·23	Lower Boggy Creek ..	Ditto ditto	Ditto ditto.

Examples 4 and 5 connect both series by the physical character of the gold and by the ratio of the metals. The belt of metamorphic slates and sandstones which furnish the examples 4 and 5 flank an area of hornblendic granite, traversed by dykes of eurite, greenstone, and syenite-porphyry. They present in places a marked resemblance in texture to some of the fine-grained examples of gneissoid schists of the Omeo district. On the other hand, No. 14 illustrates a different set of conditions, where the Lower Silurian strata are highly silicified, and are cut off by the granite without assuming any of the characteristics of the crystalline schists. In this instance, the gold belongs to the Lower Silurian series, according to its ratio, but departs from the usual character of such gold in the district by being fine-scaly.

Applying these tests to the examples No. 13 and 14 from Lower Boggy Creek, it would appear that the gold comes within the 1st series. It thus seems to be the more probable conclusion that the gold has been derived from the upper part of the watershed of Boggy Creek; and the difficulty which may present itself as to the transport of the gold down the rocky and tortuous bed of the stream will probably be met by the assumption that the detrital materials were at first deposited as marine beds on a rocky coast, and subsequently, on the elevation of the coast-line, gradually "ground-sluiced" into the present valley. This assumption is not contrary to the facts already stated, nor to the inference to be drawn from them.

The extension of the payable gold-workings into the marine Tertiaries is a question of great interest and moment. In considering it, these facts present themselves. During the earlier part of the Upper Tertiary period, and during what may be termed the deep-lead epoch, it seems that streams flowed from the mountains much as they do now, but that they emptied themselves into the Tertiary sea, which probably over-spread the area now occupied—for instance, by the Murray Tertiaries to the N. of the mountains, and the Gippsland marine Tertiaries to the S. These streams, or the lower portions of them, are now known as deep leads, such as the Welcome lead at Glenorchy, and the leads of Haddon, Chiltern, and Eldorado.

Howitt sees no reason to doubt that during the greater part of the Tertiary age, the main drainage features of North Gippsland were much as they now are; or that, in other words, the river Mitchell followed the same course through the hills that it does now, but at a higher level. He is inclined to believe that the auriferous deposits of Lower Boggy Creek have been rearranged, and the gold concentrated at and since the close of the Upper Tertiary period; but, if the Moitun Creek beds are of the same epoch as, or possibly the equivalent of, those at Glenorchy, then there should be fluvial or marine auriferous deposits of far earlier date than those from which the alluvial gold of Lower Boggy Creek appears to have been derived.

These deposits, it seems to him, might be found close to the old coast-line, as at the mouths of streams; but would be now nowhere visible, being covered up by a great depth of marine beds of late Tertiary or Post-Tertiary age. It is also possible that the conditions of the then land may have been such that the courses of the streams extended beyond the present line of hills on to which those marine beds thin out. In that case, auriferous deposits, if they exist, might be found as deep leads; or otherwise might resemble the beach-workings of New Zealand. It is only by a series of borings that the question can be determined; but in any case, the results could scarcely fail to be of great interest, and possibly might prove of great value.

In examining the country between Clifton and the Nicholson river, Howitt observed, as marking approximately the boundary between the Tertiary and older formations, that there are very widespread deposits of rounded quartz. These not only cover the hills as surface or form beds in the streams, but in places constitute "made hills." This tract has been but little prospected, and may be indicated as well worth some examination. In older Post-Tertiary times (Pleistocene ?), this tract evidently formed an extensive and shallow land-locked bay, to which Mount Lookout and Mount Taylor on the one side, and the Granite Hill and its connected range on the other side, marked the inlet. The greater part of this area is even now generally filled by Post-Tertiary and Tertiary deposits, among which quartz gravels are often predominant. These quartz gravels have evidently two origins: mainly perhaps from the E. extensions of the Upper Devonian (Iguana Creek) beds, which have now been entirely denuded, but also from the wearing down of the Silurian hills which surround this tract on 3 sides. There are grounds for the belief that the conglomerate and grits of the Iguana Creek beds are auriferous, and have supplied the gold obtained at Lower Boggy Creek, the Lower Mitchell, and elsewhere. These gravels may therefore be auriferous from this source, or as being directly derived from the Silurian strata. Thus the concentrated deposits from Clifton and the Nicholson would probably retain such gold as was set free in the process of wearing down the older formations, whether Devonian or Silurian. The question would be whether the amount of gold has been sufficiently concentrated to pay for working. As yet there are no data to decide this, nor can such data be obtained, except by actually prospecting the ground. The solution of the question is certainly of importance, as the formation referred to extends from Clifton Creek to a distance of some miles beyond the Nicholson river. An examination of it would in fact afford conclusions as to similar formations elsewhere in North Gippsland.

Gippsland [*South-West*].—According to Murray's report, the quartz workings are as yet few, and in the earlier stages of development. As is generally the case in Upper Silurian rocks, all the known auriferous quartz reefs are associated with dykes of granite, diorite, or rocks of that class, and the long persistent lines of quartz reefs which intersect the Lower Silurian rocks of the Western gold-fields are here wanting. These dykes, which are often traceable for long distances, are clearly of igneous origin, and intersect the Silurian strata both with and across the line of strike of the latter. The quartz veins traverse the dykes in various ways—vertically, from wall to wall across the dyke; vertically, parallel to it, either along the walls or in the body of the stone; and horizontally, or nearly so, from wall to wall. In exceptional instances, the quartz veins penetrate into the "country" beyond the dyke-walls, and occasionally well-defined quartz reefs cut right across the dykes, passing into the schistose rocks on either side.

These forms are also met with in combination, and small strings and leaders of quartz sometimes form a network between the larger veins.

Portions of the dykes are sometimes devoid of quartz veins ; and another feature is that occasionally, though the line of fissure and walls remain distinctly traceable, the dyke-stone itself is absent, and its place occupied by broken-up rubbly shale or slate, with thin quartz leaders.

The great dyke worked by the Walhalla and Long Tunnel companies exhibits the most extensive dyke workings in the colony, and nowhere else can a finer study of this class of mining be obtained. It runs slightly W. of N., parallel with the Silurian strata, and consists of a hard diorite, more or less impregnated with arsenical and iron-pyrites. Two large quartz lodes, meeting in an apex or cap, and known as the E. and W. lodes, accompany the dyke along or near to and within its walls, while others intersect the body of the dyke, which is also crossed in all directions by small strings and veins of quartz. The apex of the two main lodes, the cap of the quartziferous dyke-stone, and the "shoot" of auriferous quartz, all dip N., the underlie being W. At the lower levels in the Long Tunnel mine, near the shaft, the walls of the dyke continue plainly defined, but the dyke-stone is replaced by soft rubbly shale, with small quartz strings. On driving N. along this "track" of the dyke, the diorite and auriferous quartz lodes are found to "make" again, the distance to be driven N. from the shaft to strike them increasing with the depth of level.

The arsenical and iron-pyrites accompany the auriferous shoot, the proximity of which, the latter especially, is regarded as a sure indication in the two mines referred to. It appears likely that there are several such shoots along this line of dyke, of which that worked in these mines is the most explored, and that they may eventually be found to join in one main body.

The quartz mines of Foster exhibit another phase of dyke workings. A large well-defined dyke, which was found in the alluvial workings in the flat below, crosses the W. slope of the Kaffir's Hill, and has been traced for about ½ mile N. towards Turton's Creek. This dyke consists of a soft greyish-white decomposed granite of quartz, felspar, and a little white mica ; its general bearing is N. 5° W., and its thickness varies from a few ft. to nearly 250 ft. The quartz veins in the dyke are nearly horizontal, but curved and inclining slightly W., and one has been proved to extend for a long distance into the W. schistose wall. Their extent longitudinally along the dyke is as yet unproved.

The workings of the Golden Bar and No. 1 S. claims show 3 of these flat veins to exist within the depth already worked—about 100 ft. ; they rarely exceed 6 in. in thickness, and have few small tributary veins or strings; but from their highly auriferous character, and the ease with which they are worked in the soft dyke-stone, they yield fair returns. In the No. 1 S. claim, the vein traced W. into the schistose country attained a thickness of 10 in., yielding handsome returns and a number of very rich specimens. It is quite likely that sinking deeper on this dyke will show other flat veins to exist below those known at present. In the Bennison Flat claim are 2 quartz veins in the metamorphic schist; they have a N.E. strike, and both underlie with the strata N.W. Their appearance, and that of the schist, indicates the proximity of a dyke into which they will probably be found to trend. There is every indication of a line of auriferous quartz reef traversing the line of the New Zealand and Cement hills, which has been the source of the gold in the drifts which cap them, and of that obtained in Whipstick Gully. Explorations in search of this line are advisable.

The now abandoned workings on the Columbia reef, near Russell's Creek, show the existence of a decomposed diorite dyke. A diorite dyke with slightly auriferous quartz veins crosses the head of California Gully, Tangil, but has not been much worked. At Crossover, the workings of the Albion claim are on a quartz reef 6 in. to 2 ft. thick, bearing about N. 20° E., which cut across a micaceous diorite dyke, bearing about N. 70° W. From another shaft, the Happy, on the same line of dyke, another similarly occurring reef is reported to have been worked. In the Albion, the micaceous dyke-stone is in one portion of the workings replaced, between the still continuous walls, by a hard, black, gritty, finely micaceous rock, a hand specimen of which Cosmo Newbery describes as a "dense metamorphic highly siliceous shale." There are many untried dykes to which prospectors might advantageously pay attention; the best portions of the auriferous gravels of Tangil are in immediate proximity to dykes traversing the bed-rock; and in the scattered shallow diggings between the Tangil and Tarween rivers, pieces of dyke-stone are found in the wash-dirt, indicating neighbouring dykes as the source of the alluvial gold, which, by its character, also suggests the same origin.

At Turton's Creek, careful prospecting is especially to be recommended along a line of dyke which appears to be the only source whence the wonderfully rich yields from the alluvions could have been derived. This dyke crosses the head of all the gold-workings; no gold has been found in any quantity above it; and when its course and that of the creek diverge, the quantity of gold in the bed of the latter becomes less and less. The dyke has a N.E. course, and is a dense decomposed doleritic rock, consisting, according to Cosmo Newbery's report, "of augite and felspar, yielding, on qualitative analysis, silica, magnesia, iron, alumina, and lime." The dyke is accompanied on its N.W. side by a soft, black, shaly band containing thin strings of quartz. No quartz has yet been found in the dyke itself, though small veins of calcite occur. The black band has been prospected in two or three places, and the dyke was cut and driven into in one place, but unsuccessfully. The evidence is nevertheless very strong in favour of the source of the alluvial gold being in or connected with the dyke; there is no other apparent matrix, and similar dykes cross Livingstone Gully, a tributary of Turton's Creek, at the heads of various small alluvial workings. There are also in Livingstone Gully loose blocks of an extremely hard siliceous dyke-stone which Cosmo Newbery describes as "a dense siliceous elvan, containing magnetic and copper-pyrites, some portions consisting of nearly pure silica in the form of chalcedony." Howitt, who examined a specimen microscopically, believes it to be "truly a siliceous dyke, containing some iron diffused in an amorphous state." A miner acquainted with New South Wales gold-fields assured Murray that he had seen similar stone in that colony highly auriferous.

The alluvions in this part of Gippsland consist of shallow workings in old gravels on hills, as at Kaffir's and New Zealand hills at Foster; river, creek, gully, and high bank or terrace workings, where the deposits are the result of recent geological action, and the gold has been either derived from immediate erosion of local matrices during such action, or from the denudation and re-distribution of more ancient drifts; lead workings in gravels referable to the Miocene and Pliocene drift periods, of which some are above and some below the level of existing drainage channels. The principal river-workings are in the Tarween and Tangil rivers, in both of which the richest deposits of gold were found below where old gravels had been denuded, as at the mouth of Langridge's Gully, on the Tarween, and immediately below the tunnel cement workings on the Tangil. There are numerous other workings of greater or less extent and richness throughout the district, as Crossover, Deadhorse, and Livehorse gullies, Russell's Creek, Turton's Creek, and others of less note.

As regards leads, the oldest is that referred to as occurring beneath older volcanic and lignite, at the head of Langridge's Gully, W. of the Tarween river. This lead is narrow but well defined as far as followed; its presence is an indication of the existence of other similar leads beneath the neighbouring volcanic areas; fragments of dyke-stone in the gravel indicate neighbouring auriferous dykes as the probable source of the gold.

The Tangil lead is, at its upper portion, near the township, considerably above the river level; the actual head of the lead, which once probably extended as far back as that of the present river, has been removed and its course obliterated during the erosion of the latter. Having a more rapid fall than the river, the lowest workings, those of the Pioneer claim, are 60 ft. from the surface, and somewhat below the river-bed, and there is every prospect of a gradually increasing distance between the two levels. The further course of the lead, traceable by the overlying volcanic rock down to the Haunted Hill, is likely to be auriferous for that distance, though to what extent will depend on the character of any dykes or quartz veins that have been denuded in or near its channel. The Foster lead, which underlies the alluvial flat of Stockyard Creek, is 30 to 60 ft. in depth from the surface, and consists of the usual clay, drift, and gravel deposits, which are newer than the gravel cappings on New Zealand and Cement hills, coloured as Older Pliocene, though the age of both is doubtful.

The excess of water and want of machinery have hitherto prevented its continuation from being properly prospected far below the township; but the rich yields already obtained are surely a warrant for the outlay of capital for this purpose. From the great size and defined character of the granite dyke, whence the alluvial gold has evidently been derived, it seems likely to continue S. for a great distance farther than already traced, and to have other "shoots" of gold-bearing stone. Should the lead, therefore, continue along the dyke, it is very likely to renew its auriferous character as it passes such shoots, and even if not, there are other lines of auriferous quartz likely to be intersected.

In considering the prospects of Western Gippsland as a mining district, the marked difference between the Lower and Upper Silurian gold-fields should be kept in view. The Lower Silurian rocks of the great Western gold-fields are traversed by wide belts of auriferous quartz reefs, many miles in length, in which the lodes and veins are large and persistent, and though they also contain their gold in "shoots" and patches, these are not far apart, and a little gold exists through the whole body of quartz. Consequently all leads, creeks, and gullies, within such belts, contain auriferous drifts, and when they run parallel to, or cross and recross a single line of reef, or cut a number of reefs and veins at short intervals, the supply of gold has been found continuous. In Murray's report on the geology of Ballarat, the difficulty with which any but very fine free gold can be moved by water was advanced as a reason for maintaining that the quality of wash-dirt must depend chiefly on the character of the local auriferous matrices. The concentrating re-distribution of old drifts has, in some cases, caused the conveyance of associated gold some distance from any apparent matrix, and much gold has evidently travelled a long way while attached to quartz or clay; but this would only partially affect the auriferous character of a drift.

In country, therefore, where the quartz veins are small and few in number, and the shoots of gold, though rich, at wide intervals and of small surface extent, the gravel in leads, creeks, and gullies may be expected to be of corresponding character. In Upper Silurian rocks, such as those of Western Gippsland, no large belts of quartz reef have yet been proved. A few small lines of quartz reefs, traceable for comparatively short distances, or lines of dyke with auriferous quartz veins in widely separated shoots, are the usual features of Upper Silurian quartz workings in general, and those of Western Gippsland are no exception to this rule. Some of the shoots are of great richness, and, in some instances, are now being traced to considerable depths, as at Walhalla, though they only recur at wide intervals on the surface ; and the alluvial workings, though exceedingly rich in patches, cease to be remunerative when followed far from the perhaps solitary reef or dyke whence the gold was derived.

In the case of Western Gippsland, it can only be pointed out that, wherever Silurian forms the bed-rock, there is a chance of alluvial gold-workings of limited extent being found in the creeks, gullies, and gravel cappings. The country between Foster and Cape Liptrap, and from the Tarween to the Thomson, comprises many wide unprospected areas, in which there is hope of finding gold, though extensive tracks are likely to be barren. The dykes and quartz reefs already proved gold-bearing are of such a character as to justify energetic labour in tracing the auriferous shoots downwards, as it is highly probable that they will increase in size and richness with their depth from the surface. In fact, it may be said that the mining future of this part of the country depends on the success of deep-lead mining. Each isolated alluvial working may be regarded as evidence of a neighbouring auriferous matrix, for which diligent search should be made. The advisability of this search is recognized by most of the miners in such places ; but the majority of them are not in a position to undertake prospecting work, which does not afford a hope of speedy returns.

Among the areas recommended for prospecting, those occupied by Mesozoic rocks are not included. There are certainly places where, in quartz gravels resting on them, fine gold has been obtained, and, as reported, in some cases almost in payable quantity ; but such gold must have travelled with the gravels for long distances, as there are no quartz veins whatever discoverable in the Mesozoic rocks, nor are there indications of lodes or veins of other minerals likely to be auriferous. To Murray's knowledge, the South Gippsland Ranges have been very much prospected during the last 2 years, and the unvarying answer to inquiries made was, that no fresh outcrops of Silurian, like that at Turton's Creek, could be found, and that no gold could be obtained except in the vicinity of some of the quartz gravels, and then only in minute quantity. Precisely the same results have been obtained under similar conditions by prospectors in the Mesozoic ranges of the Cape Otway district. The search for other outcrops of Silurian in the South Gippsland Ranges would not be hopeless, as many tracts, much greater than that occupied by the Turton's Creek outcrop, are unexplored ; but it would appear hopeless to prospect unless such outcrops are discovered. It is quite likely that the Mesozoic beds may be auriferous at their contact with the Silurian, but whether payably so must depend on local conditions; also that the dykes and quartz reefs on the Silurian may eventually be worked beneath the Mesozoic. The assumption of the non-auriferous character of the latter is based not on geological age, but on the absence of any mineral veins in which gold or other metals might be expected to occur.

Stawell gold-field.—According to Norman Taylor's report, dated Dec. 14, 1875, this district is alone in the extraordinary complications and want of regularity in the occurrence of its reefs.

There are two main lines of so-called vertical reef—the Cross and the Scotchman—running in the strike of the country about N.W., and dipping or underlying at various angles from 60° to 90° S.W. They have also a dip in strike N. at about the same angle as the Flat reef. Besides these, are the Upper and Lower Flat reefs, at right angles to the last and possibly connecting them, as well as other flat reefs to the E. again of the Scotchman's vertical reef. These flat reefs should more correctly be called cross reefs, as they cross the strike of the country. Indications of faults are not uncommon, throwing the upper portion of the vertical reefs off to the W.; these are locally termed "slides" and "floors"; they come in from the S.W. at an angle of about 45°, with a N. and N.E. dip. "Breaks" in the reefs are also frequent, and are probably lines of fault—the quartz is fractured, and the angular pieces are cemented by carbonate of lime, derived from the water which flows through the interstices, and which is, in some places, in great quantity. A similar break is met with in the cross-cut in the E. workings (646 ft.) of the Albion Co., where the breccia is cemented by secondary pyrites. Another peculiarity is the manner in which the reefs wedge or cut out, new "slabs" of stone making in one or other of the walls. This also is probably due to a line of fault. The upheaval of the mass of intrusive granite to the S. has probably caused these lateral faults or slides, and the same forces which operated to cause them, possibly also at the same time caused the fissures, since filled by the flat reefs, which were again faulted at a later period. Taylor concludes that the granite is an intrusive mass, as it sends veins into the adjoining schists, and contains schorl or tourmaline, a mineral containing boracic acid, and a product of igneous agency. The vertical reefs are, as a rule, much poorer in gold than the flat reefs, and all are poorer in depth than they were in the old surface workings. This is due most likely to the decomposition of the pyritous schists above the water-level, and the liberation of their contained gold, to be afterwards acted upon by other agencies, and collected by segregation into the reefs.

TABLE OF THE DEEPEST MINES AT STAWELL.

Mining Companies.	Quarter ending 31st March 1874.			Quarter ending 30th June 1874.			Quarter ending 30th September 1874.			Quarter ending 31st December 1874.			Quarter ending 31st March 1875.			Quarter ending 30th June 1875.			Quarter ending 30th September 1875.		
	Depth of shaft.	Deepest level.	Deepest cross-cut.	Depth of shaft.	Deepest level.	Deepest cross-cut.	Depth of shaft.	Deepest level.	Deepest cross-cut.	Depth of shaft.	Deepest level.	Deepest cross-cut.	Depth of shaft.	Deepest level.	Deepest cross-cut.	Depth of shaft.	Deepest level.	Deepest cross-cut.	Depth of shaft.	Deepest level.	Deepest cross-cut.
	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.
Magdala	1,355	800	800	1,408	same as last		1,459	same as last		1,524	same as last		1,568	same as last		1,630	same as last		1,692	same as last	
Newington and Pleasant Ck.	1,214	660	660	1,281	same as last		1,360	same as last		1,420	same as last		1,475	same as last		1,556	same as last		1,616	same as last	
South Scotchman's	1,102	500	500	1,196	same as last		1,256	same as last		1,260	1,250	1,250	1,262	1,252	1,252	same as last			same as last		
Extended Cross Reef	890	870	870	same as last			same as last			same as last			892	870	870	same as last			same as last		
Crown Cross United	870	810	810	905	same as last		964	same as last		1,045	same as last		1,045	900	900	same as last			same as last		
P. C. Cross Reef (The North Cross) No. 2 ..	920	743	743	920	761	761	950	850	850	same as last			same as last			same as last			same as last		
P. C. Cross Reef (The North Cross) No. 1 ..	..	..	..	793	..	..	..	..	..	780	760	760	same as last			same as last			same as last		
Prince Patrick	..	..	..	..	..	..	956	..	..	1,026	..	..	1,100	..	..	1,178	..	..	1,265	..	..
West Scotchman's	..	..	..	..	..	..	..	..	..	790	..	..	855	..	..	933	..	..	997	..	..
No. 2 Crown Cross	..	..	..	..	..	..	..	..	..	746	740	740	781	770	770	..	..	..	..	..	..
Oriental	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1,004	640	..
	Tons.	Average. dwt. gr.		Tons.	Average. dwt. gr.		Tons.	Average. oz. d. gr.		Tons.	Average. dwt. gr.		Tons.	Average. dwt. gr.		Tons.	Average. dwt. gr.		Tons.	Average. dwt. gr.	
Total Quartz crushed	12,841	15 22·26		16,352	19 23·56		17,060	1 0 20·52		16,671*	16 22·87		13,065	18 23·07		16,714½	17 15·11		19,986½	19 11·13	
Total Cement crushed ..	1,962	8 1·06		2,492	6 22·21		3,254	0 7 8·32		4,206	10 11·50		4,840 9	6 21·07		5,500	7 12·35		..	..	
Particulars of last.	Where obtained.	Average.		Where obtained.	Average.		Where obtained.	Average		Where obtained.	Average.		Where obtained.	Average.		Where obtained.	Average.		Where obtained.	Average.	
Hand-in-Hand (Tregea's) ..	deep lead	9 15·33		deep lead	6 0·96		deep lead	0 12 4		deep lead	12 10·43		deep lead	7 18·64		deep lead	7 21·42		deep lead	7 20	
N. & S. Wales (Welshman's)	deep lead	6 16·63		deep lead	7 6·52		deep lead	0 6 9·32		deep lead	6 9·44		deep lead	7 5·68		deep lead	9 10·70		deep lead	6 20·28	
Band of Hope	..	..		..	..		deep lead	1 11 7·35		deep lead	18 0·28		deep lead	6 8·99		deep lead	4 12·57		deep lead	3 7·13	
Belfast	..	..		..	..		Welshman's Flat.	0 5 0·05		..	..		..	..		..	..		..	..	
New St. George	..	..		..	..		..	..		..	..		Church Hill.	3 6·78		..	..		..	..	

* 252 tons quartz from Extended Cross reef yielded 870 oz., giving an average of 3 oz. 9 dwt. per ton, and of better quality than usual.

The schistose rocks here are much decomposed to some depth, and are converted into kaolin, and contain traces, in veins and patches, of blue phosphate of iron. The water percolating through the reefs holds carbonate of lime, sulphates of lime and magnesia, and sulphate and chloride of sodium, in solution. Efflorescences of sulphate of magnesia occur on walls of the drives along the Scotchman's line of reef. The elvans or granitic dykes are probably older than the reefs, and have had no influence upon them, as in the claim of the Newington and Pleasant Creek Co., the reef passes through the elvan, and in the drives at different levels the elvan sometimes forms the head- and sometimes the foot-wall. The basalt dykes are stated by Newbery to closely resemble the basalts of the Sandhurst dykes. They contain large plates of brown mica and other minerals, and the joints are coated with carbonate of iron. They soon decompose on exposure to atmospheric influences. With regard to the water-level, some curious instances have been noticed. The old shaft in No. 7 Crown Cross United Co.'s claim was swamped out at 400 ft. some years ago, while the shaft in No. 4 in the same ground was quite dry at 800 ft. In the North Scotchman's pumping-shaft the water stood originally (in 1865) at 240 ft. from the surface. The line has since been pumped dry. At the S. end of the Scotchman's line, the water-line is now said to stand at about 300 ft. In the Emerald Isle claim, the water-level had not varied from 360 ft. for 12 months, notwithstanding the pumping in Nos. 2, 3, 4, and 5 South Scotchman's.

TABLE OF YIELD OF GOLD FROM PLEASANT CREEK CROSS REEF QUARTZ-MINING CO.'S PROPERTY.

Date.	Tons crushed.	Yield of Gold.			Dividends declared.		
		oz.	dwt.	gr.	£	s.	d.
Half-year ending 30th June, 1870	1,675	3,406	19	8	9,992	1	9
,, 31st December, 1870 ..	7,671	10,452	17	12	28,500	0	0
,, 30th June, 1871	9,402	12,667	11	12	32,250	0	0
,, 30th December, 1871 ..	12,131	24,495	7	18	73,500	0	0
,, 30th June, 1872	9,265	17,031	13	18	49,500	0	0
,, 31st December, 1872 ..	13,006	20,682	4	12	59,000	0	0
,, 30th June, 1873	9,292	14,188	9	0	40,500	0	0
,, 6th January, 1874	13,971	15,081	6	21	36,000	0	0
,, 30th June, 1874	14,020	17,894	14	12	45,000	0	0
,, 31st December, 1874 ..	12,969	20,766	5	16	58,000	0	0
,, 30th June, 1875	11,253	14,542	0	6	35,000	0	0
Three months ending 30th September, 1875	6,271	6,731	4	20	23,000	0	0
Totals	120,926	177,940	15	11	490,242	1	9

Total average of 1 oz. 9 dwt. 10 gr. per ton.

Sandhurst. North Waranga.—This district was reported on by William Nicholas, in September 1877. The Waranga gold-fields were first opened in the latter part of the year 1853. They may therefore be reckoned amongst the oldest of Victorian gold-fields; and, by this time, as may well be understood, nearly all the gullies are wrought, and some worked over again and again, still yield a livelihood to a considerable number of miners. The name was obtained from the native title of the squatter's run on which the first gold-discoveries were made.

The most N. and most important gold-workings are at and in the vicinity of Rushworth, where, at the close of the September quarter of 1877, 513 alluvial miners were employed in mining. The principal alluvial workings are, or have been, on the Old lead. The head of the lead is in Growler's Gully, at the back and to the W. of the township. This lead trends E., and probably terminates in the Waranga Swamp. Many rich tributaries flow into it, but those joining it on the S. side are the most considerable. This lead has yielded more gold than any other in the district; it is but shallow, as the deepest shafts sunk on it are only 35 to 55 ft. in depth. The character of the cement and wash-dirt in the lead is very like the Deep lead at Bendigo, and both are probably of the same age (Older Pliocene: oldest gold-drift). Other minor auriferous streams flow into the Waranga Swamp, but they have as yet received little attention. Whether Waranga Swamp, the receptacle of these golden creeks, will ever pay to work, is a matter that can only be decided by the miner. It is, however, not unreasonable to conjecture that the basin occupied by it is auriferous.

To the W. of Rushworth, is situated the Castle Lonely lead; the sinking here ranged from 20 to 30 ft. in depth, and the wash-dirt was 1 ft. to 2 ft. 6 in. thick. This lead appears to be connected with Chinaman's Flat and Old Ned's Gully, and it has been inferred that if the lead were followed farther towards the N., the widespread wash-drift would be found to become concentrated and form into a more regular lead.

Nuggety Gully, the main feeder or tributary to the Old lead, crosses the Nuggety reef in its N. course. This gully was very rich; the gold found in it was of a rather pale colour, and little, if at all, water-worn; the wash-dirt was of a very ferruginous character, and contained a large quantity of bean iron-ore (magnetic); there was also sub-angular quartz. The very ferruginous character of the wash-dirt is not surprising, seeing that the Nuggety reef, at the head of the gully, contained such a large proportion of iron-ore.

Rushworth alluvial gold ranges in assay between $21 \cdot 3\frac{3}{8}$ and $22 \cdot 1\frac{1}{8}$ carats, with a loss in melting of $1\frac{1}{2}$ per cent. The average buying price (with standard at *77s.*) is *76s. 9d.* to *77s.*

About 4 miles S. of Rushworth are situated the auriferous deposits at Whroo, in a distinct but adjoining basin. Alluvial mining here has been carried on principally in the Main Gully, the Union lead and its tributaries. These auriferous streams take their rise in the neighbourhood of Balaclava Hill, and trend in a S.E. direction towards the Reedy

Swamp. The overflow waters of this swamp pour into the Goulburn river. The deepest sinking in the alluvions is on the Union lead, and ranges from 35 to 55 ft. in depth. This lead has been traced nearly to the swamp, and nearer to it than the operations carried on thus far upon the Main Gully. The wash-drifts of all the gullies on the S.E. fall from Whroo are connected with the Union lead. The cement and wash-dirt of the lead are of much the same character as those found in the Old lead at Rushworth.

The wash-dirt in the Cemetery lead, at Whroo, was 18 in. thick, and yielded as much as 1 oz. of gold to the load. Whroo alluvial gold is much better than that from Rushworth. The average assay is $22 \cdot 1\frac{7}{8}$ carats; buying price, 77*s.* 6*d.* Loss in melting $1\frac{1}{2}$ per cent. The gold from some gullies assays as much as $22 \cdot 3\frac{5}{8}$ carats.

Coy's diggings lie to the S. of Whroo, and are distant from it about 6 miles. A non-auriferous low barren range, composed of arenaceous sandstone, separates the gold-workings of these two fields. The shallow alluvial gullies at Coy's trend in a N.E. direction into the same water-shed as the Whroo auriferous drifts; so far as they have been developed these deposits are of little importance. The operations have been almost confined to Coy's, Burrens', and Hard-scrabble gullies. In the latter, the wash-dirt was 10 to 12 in. thick. The depth of sinking generally ranged from 4 to 12 ft., and the yields during the first 12 months' mining varied from 4 dwt. to 1 oz. 4 dwt. per load of wash-dirt. The rocks forming the hills round which the gullies trend are more argillaceous than those prevailing at Whroo and Rushworth.

The alluvial works at Cherry-tree Flat, which lie about 2 miles to the S.E. of Coy's diggings, are confined to the flat and two small gullies which fall into it. The alluvial deposits are relatively unimportant as compared with the auriferous quartz reefs.

To the W. of Whroo, and about 5 miles distant, on the M'Ivor road, are situated the Nine-mile Creek diggings. The depth of the alluvium at this place varies from 6 to 25 ft. A section of the sinking at the latter depth is made up of surface soil, clay, white cement, a very heavy deposit of quartz boulders and wash-dirt (12 to 20 in. thick, which yielded 4 to 18 dwt. to the load). The hills here are of the kind named by miners "made hills," and they are probably of the same age as the White Hills of Bendigo (Older Pliocene: oldest gold-drift). The main lead has been worked for 2 miles in length, and tributary gullies have also been mined. On this lead, the shallow sinking was at a lower level as regards surface elevation than the deep sinking, and the cement and wash-dirt were less in thickness, width, and richness than at higher levels, where the auriferous wash was found at greater depths. Like circumstances are not uncommon in some of the important Western gold-fields of Victoria. In this instance, it appears to have been caused by the new watershed deviating from the old one, crossing it at a low level, removing and re-distributing the overlying detritus and the wash-dirt.

The thickness of the alluvium at Good Friday Creek, which is situated a few miles S. of the Nine-mile, is 40 ft. It consists of surface soil and gravel, cemented clay and gravel, and a compact argillaceous sand deposit (false bottom) and wash-dirt, 6 to 12 in. thick.

At Fontainebleau, which lies midway between the Nine-mile and Good Friday, a little alluvial mining has been done.

The only large nugget discovered in any of these Waranga gold-fields was one which weighed 60 oz. It was found at Siberia, in October 1863. The scarcity of nuggets exceeding 5 oz. in weight is a remarkable feature in connection with the history of these gold-fields. The auriferous alluvial deposits at Siberia are confined to two small patches, each of about ½ mile in length, which are separated by a range through which runs an E. and W. quartz reef.

At Friesland (North Spring Creek), which is situated on the E. branch of Spring Creek, the sinking was 20 to 30 ft. in depth, the wash-dirt was about 15 in. thick, and the yield of gold was 5 dwt. to the load.

Shallow alluvial mining has been carried on to a considerable extent in the numerous gullies which wind between the Buffalo Ranges. These lie E. of Whroo, and between it and the Goulburn river. The "old lead," here at 25 ft. in depth, proved to be narrow, only about 8 ft. in width; the wash-dirt was 18 in. to 4 ft. thick. At 4 miles N. of this lead, wash dirt was found 1 ft. thick at 6 ft. in depth, and yielded over 12 dwt. to the load. The want of permanent water is the one great difficulty which retards the development of the undoubtedly payable auriferous deposits at the Buffalo Ranges.

Near Mount Black, a little gold has been obtained by alluvial prospectors.

Immense deposits of cement cover considerable areas of the country about Rushworth, Whroo, Nine-mile, and Fontainebleau. The cement lies exposed on the surface in places, and has never been found at other than what may be considered shallow depths. It has been extensively worked at the under-mentioned places, yielding remunerative quantities of gold, and frequently rich patches—Chinaman's Hill, Gravel Pits, Old lead, Nuggety, Cockatoo, Rushworth township, Butcher's Gully, &c. Crushings of several hundreds of tons have from time to time been recorded, which have produced 6 to 10 dwt. of gold to the ton, and there can be little doubt that as rich cement still remains to be crushed as has been put through the mills in the past.

The quartz reefs near Rushworth, with only 3 exceptions, have an E. and W. direction in conformity with the strike of the strata in which they occur. The reefs, however, underlie to the N. very quickly and irregularly, whilst the strata are nearly vertical. A transverse section would show the dip of the reefs to be broken like a series of steps. There are about 40 reefs which, by reason of their E. and W. strike, may be called cross-reefs, as they run at right angles to the prevailing strike of the auriferous reefs in Victoria. They are characterized by very rich patches of golden stone. The gold in the reefs which run N. and S. is evenly distributed, and the reefs dip both E. and W., but do not show evidence of "saddle" formation. The veins range in thickness from 6 in. to 6 ft.

TABLE OF QUARTZ REEFS NEAR RUSHWORTH.

Name of Reef.	Strike (magnetic).	Dip.	Width.		Depth of shaft.
			ft.	in.	ft.
Perseverance	E. and W.	N.	..		573
Nuggety	N. 88° E.	N.	2 to 3	0	..
South Devon	N 88° E.	N.	..		..
South Nuggety	N. 87° E.	..	3 to 4	0	..
Scrub	N. 87° E.	N.	..		..
Frenchman's	N. 82° E.	..	0	6	240
Eclipse	N. 82° E.	..	..		..
Mongolian	N. 82° E.	..	..		..
Main Gully	N. 82° E.	..	..		..
Ahern's	N. 79° E.	..	..		..
Mousey's	N. 79° E.	N.	..		..
Lancashire	E. and W.	..	..		..
Charcoal	N. 78° E.	..	..		..
Welcome	E. and W.	..	..		..
Belfast	N. 74° E.	..	..		..
Sons of Freedom	E. and W.	..	..		..
Luna	E. and W.	N.	..		..
East Nuggety	E. and W.	..	..		..
Union	E. and W.	..	..		..
Westlake	N. and S.	E.	..		..
Specimen Hill	E. and W.	N.	..		..
Dunlop's	E. and W.	N	..		..
Dunlop's	N. and S.	W.	..		..
Result or Black	..	..	2	0	..
Hope of Denmark	E. and W.	..	0	6	145
Scandinavian	E. and W.	..	..		..
West Growler's	E. and W.	..	7 to 17	0	130
Corroboree	E. and W.	..	..		..
Forlorn Hope	E. and W.	..	0 to	½ 6	65
Anstead's	E. and W.	..	..		..
Schleswig-Holstein	E. and W.	..	0	5	200
Black Joe's	E. and W.	..	..		..
Cumberland	E. and W.	..	..		..
Growler's	N. and S.	E.	..		..
Crocker's	E. and W.	..	..		..
Chinaman's	E. and W.	..	..		..
Fossil	E. and W.	..	..		..
Diamond	E. and W.	..	..		..
Cockatoo	E. and W.	N.	..		..
Erin-go-Bragh	E. and W.	..	0	6	170
Camp	E. and W.	..	..		..
Hit-or-Miss	E. and W.	..	0	6	170
J. O. R.	E. and W.	..	1	6	20
Good Luck	E. and W.	..	2	0	30
Bowman	E. and W.	..	..		..

There has been but one deep shaft sunk on a quartz reef, and that reached a depth of 573 ft. It is situated on the Nuggety reef. This shaft was sunk by the Perseverance Co., who obtained 9 oz. of gold to the ton at 330 ft. in depth; 1 oz. to 1 oz. 5 dwt. to the ton of quartz raised from 450 and 460 ft.; 1 oz. 15 dwt. 18 gr. of gold from 651 tons got from 510 ft. in depth; and good yields from various other considerable depths. Scarcely a shaft has been sunk below the water-level on any of the other reefs, although many of them have proved very rich above that level. The quartz of the veins above the water-line is of a dull vitreous appearance; the natural fractures of the vein-stone are more or less covered by ferruginous clay and oxide of iron, which latter is at times a full inch in thickness, and very little pyrites is visible. Galena occurs in small quantities with fine gold in the solid quartz in the Doctor's reef at the White Hills.

The auriferous reefs at Whroo, in general terms, may be said to differ but little from those at Rushworth. The only noticeable exceptions are the Balaclava Hill veins, the Albert reef, and the Stockyard reef. In each of these lodes, the occurrence of antimony veins, or the association of antimony ores in the auriferous veins, is a marked feature.

TABLE OF REEFS NEAR WHROO.

Name of Reef.	Strike (magnetic).	Dip.	Width.	Depth of shaft.
			ft. in.	ft.
Prince of Wales	N. 88° E.	..	..	..
Victoria	N. 87° E.	45°	0 6 to 6 0	200
Carr's	N. 87° E.	N.	0 6 to 6 0	200
Johnson's	N. 87° E.	..	..	..
Albert	N. 87° E.	N.	0 1 to 12 0	240
Happy-go-Lucky	N. and S.	W.	Broken veins	.
King David	N. 78° E.	..	..	..
Stockyard	N. 59° E.	N.	0 6	180
Malakhoff	N. 38° W.	..	..	..
Balaclava	N. 20° W. and N. 15° E.	W.	Not known *	450
Peep-o'-Day	N. 65° E.	N.	..	200
Anglo-French	N. and S.	W.	1 0	130
Scotchman's	N. 25° W.	E.	2 0	150
Woodward's	E. and W.	..	1 6	180
Black	E. and W.	60°	3 0	220
Jerry's	N. and S.	..	1 8	50
Welch's	E. and W.	N. 60°	1 6	300
Rose of Denmark	E. and W.	N.	1 0	40

* Network of quartz veins and spurs as much as 100 ft. in width has been broken and crushed.

TABLE OF REEFS AT COY'S DIGGINGS.

Name of Reef.	Strike (magnetic).	Dip.	Width.		Depth of shaft.
			ft.	in.	ft.
Coy's	N. 82° E.	..	..		..
Hit-or-Miss	N. 67° E.	..	..		..
Murray *	N. 2° W.	W.	0	11	..
London	N. 2° W.	..	1	6	220
Blackwall	N. 2° W.	..	..		..
Byron	N. 24° W.	W.	24 to 1	0 to 6	185
Hick's	N. 29° W.	..	0	4	..
Welcome	N. 32° W.	W.	0	6	170
Guernsey	N. 43° W.	..	..		..
Morning Star	N. 45° W.	W.	2	0	175
Inifer *	N. and S.	W.	1	0	..
Whistler's	N.W.	W.	1	0	90
White Elephant	N.W.	..	0	5	65
Albion	..	..	0	1	149
Bailey and Mason's	N. and S.	W.	0	3	95
Myers and Fyple's	N. and S.	W.	0	3	70
Taylor and Murray's	N and S.	W.	1	0	90
Liverpool	N. and S.	E.	0	2	130
Corbett and O'Brien's	N. and S.	W.	0	2	90

* These quartz reefs contain antimony.

TABLE SHOWING AVERAGE YIELD OF GOLD FROM PARCELS OF QUARTZ CRUSHED DURING 10 YEARS ENDED 1876 IN THE WARANGA NORTH SUBDIVISION.

Year.	Tons crushed.		Total produce.			Average yield per ton.		
	tons	cwt.	oz.	dwt.	gr.	oz.	dwt.	gr.
1867	14,760	0	9221	18	0	0	12	11·9
1868	14,854	0	6434	16	0	0	8	15·93
1869	10,029	0	5631	3	16	0	11	5·51
1870	15,111	0	6824	13	6	0	9	0·78
1871	9,091	0	4732	1	21	0	10	9·85
1872	7,803	0	3113	2	0	0	7	23·50
1873	8,321	0	3341	18	20	0	8	0·78
1874	5,058	0	3737	17	6	0	14	18·72
1875	2,442	0	2654	7	4	1	1	17·74
1876	2,307	10	2371	14	1	1	0	13·36

WESTERN AUSTRALIA.—According to Brown's report (1873) on the geology of that portion of the colony lying S. of the Murchison river, and W. of Esperance Bay, gold has been found in small quantities at Peterwangy, on the Irwin river, and at several other places all over the colony, but as yet not in payable quantities. At Peterwangy, it occurs in alluvial detritus, the bed-rock being a quartzose granite (with no mica), pierced by greenstone-trap dykes; these are overlaid towards the lower ground by beds of nodular ironstone, sandstone, and grit. The difficulty encountered in sinking through the overlying deposits, and the expense, have hitherto prevented the deep ground being tested. To prove the ground, a series of shafts would have to be sunk through the hard sandstones, grits, &c., on to the granite; these would show whether old water-courses existed on the bed-rock, and whether they contain wash-dirt. The formation does not resemble any auriferous formation that Brown had ever seen, and, owing to the hardness of the ground, it is likely to be a long time before it will be tested. The result of the prospecting operations which he superintended there was the discovery of a few colours of gold in quartz in greenstone. A shaft was also sunk 47 ft. through sandstone and hard grit, without reaching the bed-rock. The influx of water prevented any greater depth being reached.

The country which he thinks most likely to be auriferous has in many places bed-rock and quartz veins identical in character and position (with regard to the granite) with the auriferous rocks of Victoria. It is highly probable, that as we hear of gold being found at Port Darwin and other places to the N.E. in South Australian territory, the auriferous country may extend into this colony. The following list includes most of the places which are likely localities for gold:—Murchison river, near the Great Bend; Tallering district; Weld Range; Blue Mountains, and eastward; Stirling Range; Mount Barren and Eyre Ranges; Phillips and Jerdicart rivers. As these localities are, most of them, at a distance from settlements, and difficult to reach except in favourable seasons, prospecting them would cost much time and money, unless indeed a surface examination was alone made, by washing the drift material in the beds and banks of creeks and gullies.

Malcolm Fraser, Esq., Surveyor-General of the colony, in forwarding a copy of the geological report from which the above information is gathered, very kindly adds:—"A somewhat extensive search was made, following on the publication of this report, by three parties of miners who came, subsidized by this Government, from Victoria. There were no good results, although the colour has been got at the places indicated on the map.

"I have had some experience myself in gold-fields, and feel rather astonished that payable gold has not been found in the reefs. As yet they have all proved barren, although numerous samples have been analysed in Victoria, and some crushed there, besides a good deal crushed in this colony in a 5-stamper battery that was obtained from Ballarat.

"The little scaly gold that was found at Peterwangy in 1870 was got in shallow paddocks. No lead was ever found, and wages could not be made at it."

EUROPE.

AUSTRO-HUNGARY.—Dr. Soetbeer gives the following table of the relative gold-production of Austria and Hungary in the years 1860–75 :—

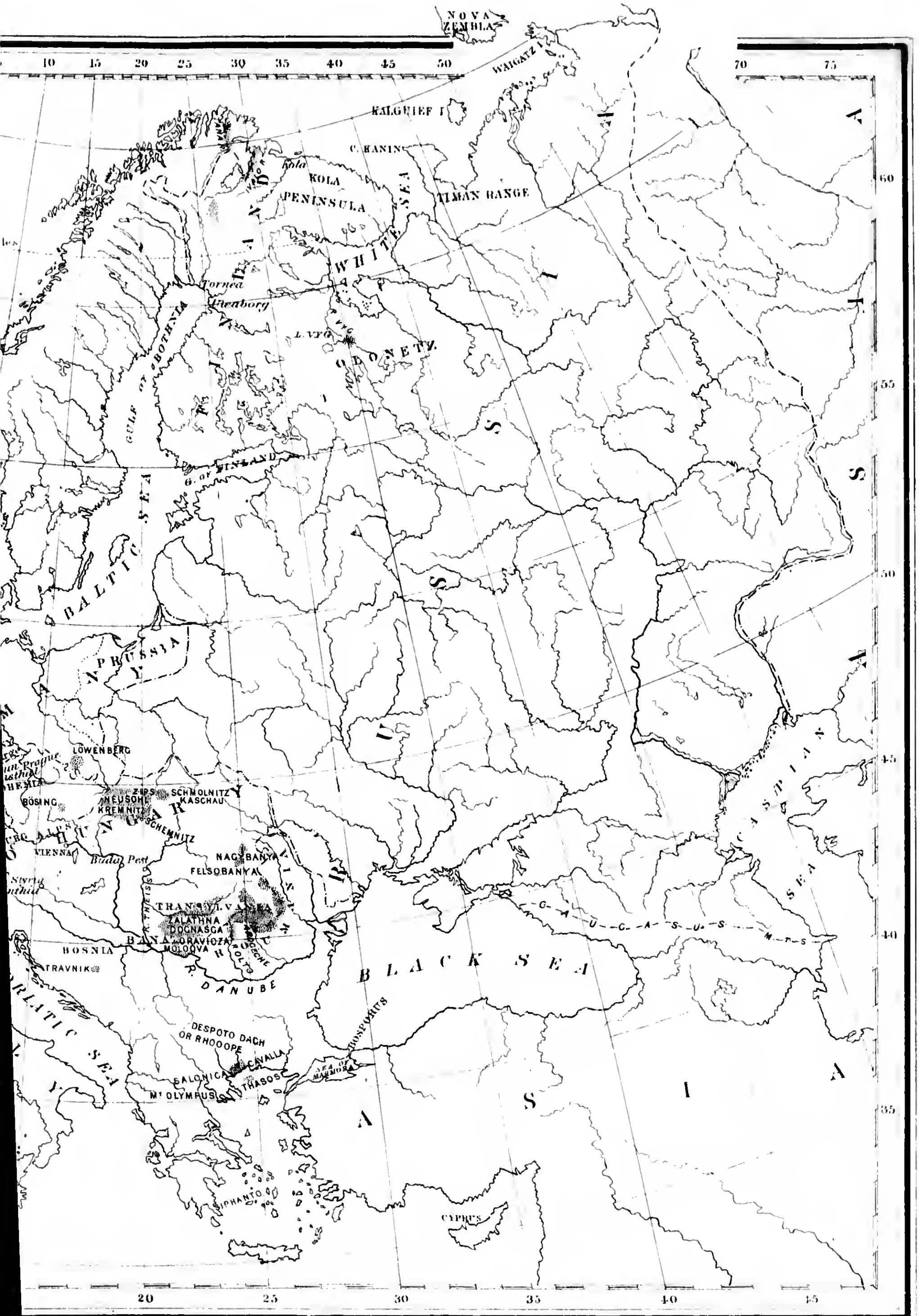
Year.	Austria.	Hungary.	Total.
	lb.	lb.	lb.
1860	39·5	3151·2	3190·7
1861	41·7	3134·5	3176·2
1862	42·6	3417·3	3459·9
1863	31·3	2996·2	3027·5
1864	51·2	3546·8	3598·
1865	53·4	3594·5	3647·9
1866	48·	3229·	3277·
1867	47·6	3654·6	3702·2
1868	42·8	3321·4	3364·2
1869	32·	3114·7	3146·7
1870	32·2	2964·7	2996·9
1871	17·9	2784·3	2802·2
1872	19·2	2868·3	2887·5
1873	10·6	2466·8	2477·4
1874	29·2	2582·	2611·2
1875	29·	3153·9	3182·9

In 1862, the gold-yield of the various districts was :—Tyrol and Salzburg, 42·7 lb.; Neusohl [Beszterczebánya], 665·3 lb.; Kaschau, 15·3 lb.; Nagybánya, 71·7 lb.; Oravicza, 23·9 lb.; Zalathna (Transylvania), 2350·3 lb.

The total gold-production of the Austro-Hungarian empire in the years 1493–1875 is stated by Dr. Soetbeer in German weights and values, which may be translated as follows :—

Periods.	No. of Years.	Total.	Annual Average.	
		lb.	lb.	£
1493–1520	28	123,200	4400	279,000
1521–1544	24	79,200	3300	209,250
1545–1560	16	35,200	2200	139,500
1561–1580	20	44,000	2200	139,500
1581–1600	20	44,000	2200	139,500
1601–1620	20	44,000	2200	139,500
1621–1640	20	44,000	2200	139,500
1641–1660	20	44,000	2200	139,500
1661–1680	20	44,000	2200	139,500
1681–1700	20	44,000	2200	139,500
1701–1720	20	44,000	2200	139,500
1721–1740	20	44,000	2200	139,500
1741–1760	20	44,000	2200	139,500
1761–1780	20	44,000	2200	139,500
1781–1800	20	56,320	2816	178,560
1801–1810	10	21,120	2112	133,920
1811–1820	10	22,000	2200	139,500
1821–1830	10	24,970	2497	158,332
1831–1840	10	35,750	3575	226,687
1841–1850	10	42,900	4290	272,025
1851–1855	5	19,525	3905	247,612
1856–1860	5	17,160	3432	217,620

EUROPE
SCALE
English Miles
SCOTLAND
ENGLAND
IRELAND
WALES
GULF OF BOTHNIA
BALTIC SEA
PRUSSIA
FRANCE
ITALY
AUSTRIA
HUNGARY
SWITZERLAND
ADRIATIC SEA
AFRICA
BOSNIA
LUGO
Valenza
Braganza
Salamanca
Jadraque
GRANADA
JAEN
Barcelona
Arcachon
Crossac
CEVENNES
PYRENEES MTS
HUESCA
FOIX
Hanover
Brunswick
Clausthal
Wiesbaden
SAXONY
Bingen
Katzenthal
Mannheim
Colmar
Basel
Felsberg
TYROL
VIENNA
Prague
BOHEMIA
LOWENBERG
BÖSING
NEUSOHL
KREMNITZ
SCHEMNITZ
Styria
Carinthia
Piacenza
Novi
TRAVNIK
Buda Pest
BANAT
TRANSYLVANIA
MOLDOVA
SALONICA
MT OLYMPUS
Cornwall
Devon
Somerset
Clevedon
Worcester
Bromsgrove
Dolgelly
Barmouth
Llandovery
Kirkcudbright
Dumbarton
Dunoon
Perth
Strathearn
Aberdeen
Banff
Forfar
Angus
SCARABEN MTS
HELMSDALE
Broughton in Furness
Lancashire
Wicklow



THOS KELL & SON LITH ... GARDEN

Periods.	No. of Years.	Total.	Annual Average.	
		lb.	lb.	£
1861–1865	5	18,590	3718	235,755
1866–1870	5	18,150	3630	230,172
1871–1875	5	15,345	3069	194,602
		Total production.		
1493–1850	358	924,660 lb., value 58,631,850*l.*		
1851–1875	25	88,770 ,, ,, 5,628,800		
1493–1875	383	1,013,430 lb., value 64,260,650*l.*		

The production of gold-yielding ores in 1875 was 1101 metric centners (of 110¼ lb.), value 11,500 florins (of 1*s.* 10*d.*); in 1876, 1750 met. cent., value 12,200 fl. The production of gold in 1875 was 0·14 met. cent., value 15,300 fl.; in 1876, 0·13 met. cent., value 17,500 fl.

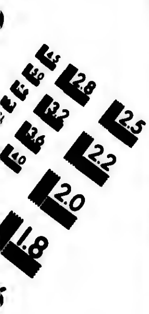
The production of auriferous ores in 1878 was as follows:—

	County Mining District.	Produce.			Value.		Average value per weight unit at the mine.		
		State.	Private.	Total.					
		kilo.	*kilo.*	*kilo.*	*fl.*	*kr.*		*fl.*	*kr.*
Ores containing gold, silver, lead, and copper.	Hungary—								
	Neusohl ..	1,577,275	654,377	2,231,652	410,303	14	100 *kilo.*	18	38·5
	Zalathna ..	2,148,553	1,484,284	3,632,837	587,023	45	,,	16	15·9
	Total ..	3,725,828	2,138,661	5,864,489	997,326	59			
Gold and silver stamp ores.	Hungary—								
	Neusohl ..	72,027,400	29,445,700	101,473,100	517,525	95	100 *kilo.*	0	51
	Nagybánya	632,526	131,312	763,838	75,435	93	,,	9	87·5
	Oravicza ..	..	2,510,000	2,510,000	8,488	80	,,	0	32·9
	Zalathna ..	..	..	..	..		..		..
	Total ..	72,659,926	32,087,012	104,746,938	601,450	68			
Gold "Schlich," small ore.	Hungary— Nagybánya	1,819,987	2,419,609	4,239,596	236,088	86	100 *kilo.*	5	56·8

The *kilo.* = 2·2 lb.; the *fl.* = 1*s.* 10*d.*; the *kr.* = $\frac{1}{50}$*d.*

The production of metallic gold in 1878 was:—

County Mining District.	Produce.			Value.		Average value per weight unit at the mine.		
	State.	Private.	Total.					
	kilo.	*kilo.*	*kilo.*	*fl.*	*kr.*		*fl.*	*kr.*
Hungary—								
Neusohl ..	166·3883	57·3692	223·7575	312,141	85	1 *kilo.*	1,395	0
Buda-Pest ..	..	1·6806	1·6806	2,239	65	,,	1,332	65
Nagybánya ..	119·9930	217·5004	337·4934	470,803	46	,,	1,395	0
Oravicza ..	..	2·9280	2·9280	3,953	10	,,	1,350	0
Zalathna ..	355·1861	886·1539	1,241·3400	1,731,669	30	,,	1,395	0
Total ..	641·5674	1,165·6321	1,807·1995	2,520,807	36			


2.8
2.5
2.2
2.0
1.8

1.0

The surface-mining measures in work in 1878, stated in sq. *mètres* (of 10·76 sq. ft.), for gold, silver, and copper, were :—

County Mining District.	State.	Private.
	sq. m.	sq. m.
Hungary—		
Neusohl	575,464·2	89,196·9
Nagybánya..	119,840·0	26,866·0
Zalathna	..	391,879·4
Grand total in 1878 ..	695,304·2	507,942·3
,, ,, in 1877 ..	695,304·2	340,124·3

The true mining measures in work for the same period and same metals were :—

County Mining District.	State.	Private.
	sq. m.	sq. m.
Hungary—		
Neusohl	35,084,848·7	18,147,179·5
Buda-Pest	..	1,507,349·5
Nagybánya..	8,611,761·0	9,609,891·0
Oravicza	..	8,892,438·6
Szepes Igló	568,045·8	7,984,338·8
Zalathna	1,738,385·4	8,639,826·6
Grand total in 1878 ..	46,003,040·9	54,781,024·0
,, ,, in 1877 ..	46,048,087·2	52,181,600·2
More in 1878 ..	..	2,599,423·[illegible]
Less in 1878 ..	45,046·3	..

It may be approximately said that the chief places where gold is worked in the Austro-Hungarian empire are (1) Zalathna, in Transylvania, and the streams fed from the neighbouring hills; (2) the Schemnitz and Kremnitz district, in Hungary proper; (3) Pribram and Joachimsthal, in Bohemia. Nearly 150,000 tons of auriferous and argentiferous ore is raised yearly, affording 60,000 to 70,000 oz. of gold and about 1,500,000 oz. of silver. Of the total gold, 54 per cent. is produced in Transylvania, and 44 in Hungary.

Bohemia.—The gold-mines and -washings of Bohemia were alluded to by Agricola already in 1546, especially those at Teschelwitz, Eule, Stechowitz, and Pless. Bohemia, in 1870, produced 156 cwt. of gold-ore. In the sixteenth century, under Friedrich III., there was a not unimportant mining industry in the neighbourhood of Alt-Albenreut, and a small quantity of 22-carat gold was produced, but it has been declining ever since. Another locality is named Goldbründl, to the N. of Grün, near the Saxon border, where grains of gold are found. In the so-called Goldau, S.W. of Unter-Rothau, gold has been procured for 70 or 80 years. It is also evident that between 1575 and 1600, besides silver, copper, &c., gold was obtained in the district of Graslitz. Traces of it have likewise been met with in the neighbourhood of Gotteshab and Platten, and between Joachimsthal and Arletzgrün.

At Eule, about 12 miles from Prague, gold-mining operations were abandoned for a considerable time, owing to the great difficulties of working, but were resumed in 1864, after the completion of an adit level. Besides their local importance, these workings also present points of general interest. The gold is found in lodes and small branches, varying from ¼ in. to several ft. in width, which occur in a crystalline clay-slate bordering the granite. The vein-mass is arranged in a banded form, and is principally composed of quartz, less frequently of calcspar, and still less frequently of chlorite. The veins are also sometimes filled up with clay intermixed with fragments of the neighbouring rock. The only ores occurring are iron-pyrites, with its products of decomposition, and native gold. This latter is found finely disseminated through the large compact masses of quartz, in grains in the smaller quartz branches, and in a laminated or crystalline form in the decomposed quartz; accompanied, in each case, by the products of the decomposed iron-pyrites. There is an intimate connection between the occurrence of the iron-pyrites and that of the gold; and the former is not only contained in the lode, but also in the country-rock. The gold is mostly found in the branches at their points of contact with branches of quartz.

According to Posepny, the central gneiss of the Hohen Tauern (apparently embracing the Rhætian and Noric Alps), and the later crystalline schists which flank it, are traversed by auriferous veins, which are mostly true "deep-fissures." The filling or vein-material is not always distinctly arranged, as in the typical fissure-veins of banded structure; but this is a peculiarity in the gold-quartz veins of other regions of similar country-rock. The vein-material consists chiefly of quartz, deposited from aqueous solution, and the products of friction between the vein-walls. The quartz, as is everywhere the case in the gold-bearing veins which traverse the crystalline schists, is permeated by little cracks or veinlets, which are filled with quartzose cement, usually of dark colour, and sometimes show gold, or sulphurets of other metals. This marbled or ribboned quartz is familiar to gold-miners in California also, as a favourable material. Among the minerals are scheelite, molybdenite, stibnite, and even (very rarely) true silver ores. But all these occur comparatively seldom. The principal ores are the sulphurets of iron, copper, lead, and zinc; gold exists in the same veins, and often intimately associated with these minerals.

In his discussion of the auriferous character of these deposits, Posepny makes two principal groups of gold-occurrences, distinguished, in his view, by the methods of treatment they require rather than by a real difference in the chemical condition of the gold. The first group comprises the gold which can be won by crude amalgamation, and which is generally termed "free gold." But his *Freigold* is that only which is visible to the naked eye; the rest of this group constitutes his class of "mill-gold" (*Mühlgold*). The second group comprises the gold which escapes amalgamation. Here also he makes two classes: the "pulp gold" (*Schlichgold*), which is found in the heavy parts of the pulp or tailings; and the "ore gold" (*Erzgold*), which is not crushed in the battery at all, but, occurring in the more massive sulphurets, which are sorted out by hand, is sent with these to the smelting-works.

Bosnia.—According to Lieut. Arbuthnot (1862) Tahir Pacha, the Governor of Bosnia, was about this time informed of the existence of some gold-mines near Travnik, and ordered Hadji Ali to obtain samples for transmission to the Porte. This he did, taking care to retain all the valuable specimens, and forwarding those of inferior quality, which, on their arrival at Constantinople, were declared worthless. No sooner was this decision arrived at, than Hadji Ali imported the necessary machinery and an Austrian mechanic, to separate the gold from the ores, and in this way amassed immense wealth.

Carinthia.—Strabo (bk. iv. c. vi. § 12: Bohn's library, i. 310) says Polybius tells us that in his time the gold-mines were so rich at Aquileia (at the head of the Adriatic), but particularly in the countries of the Taurisci Norici (comparing ancient and modern maps, these people seem to have occupied Carinthia and Styria), that on digging 2 ft. below the surface, gold was found, and the diggings generally were not deeper than 15 ft. In some instances, the gold was found pure in lumps about the size of a bean, and which diminished in the fire only about $\frac{1}{8}$; and in others, though requiring more fusion, was still very profitable. Certain Italians aiding the barbarians in working the mines, in the space of 2 months the value of gold was diminished throughout the whole of Italy by $\frac{1}{3}$. The Taurisci, on discovering this, drove out their fellow-labourers, and only sold the gold themselves. Now, however, the Romans possess all the gold-mines. Here, too, as well as in Iberia [Spain], the rivers yield gold-dust as well as the diggings, though not in such large quantities.

Prof. H. Höfer, of Pribram, has compiled the following estimate of the gold-production of Carinthia:—

Periods.	No. of Years.	Total.	Annual Average.	
		lb.	lb.	£
1493-1520	28	..	..	..
1521-1544	24	5,265	219	13,919
1545-1560	16	7,700	484	30,550
1561-1580	20	8,360	418	26,585
1581-1600	20	3,355	165	10,636
1601-1620	20	363	17½	1,157

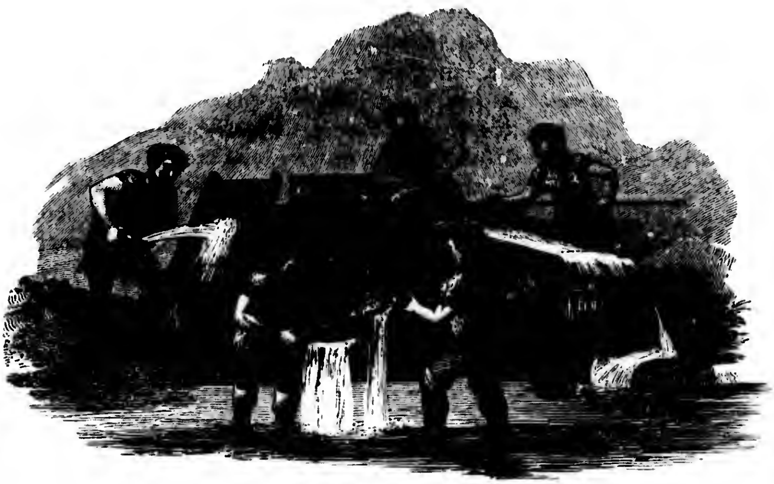
These figures would necessitate a proportionate addition to Dr. Soetbeer's comprehensive table on pp. 698–9.

Hungary and Transylvania.—The chief gold-producing centres of Hungary and Transylvania are (1) Zalathna and Abrudbánya, with the neighbouring streams, (2) Kremnitz, (3) Schemnitz, (4) Nagybánya, (5) Felsöbánya, (6) Zips, and (7) the Bannat. Agricola speaks of these mines in the sixteenth century as having been worked over 1000 years, which would date them back to the sixth century, while other accounts give the eighth century. They have continued to be exploited to the present with apparatus of the most primitive simplicity.

Trajan allowed the Dacian gold-mines to be worked by a sort of joint-stock company (*collegium aurariorum*). Between the first Punic war and the Empire, there was an immense production of metal, great waste in the extraction, and consequent exhaustion of the mines. This the emperors tried to remedy by taking the mines into their own hands to work; but this applied only to those already opened: they allowed private adventurers to discover and explore new ones. From the silence of the later historians, it may be inferred that mining in the Roman empire declined rapidly after the third century, and ceased entirely after the barbarian invasions in the fifth century. It would seem from some of Pliny's remarks, that the ancient form of the modern hydraulicing, so extensively carried on in Spain, was not unknown in Hungary. Chalmers (1880) remarks that for a century and a half, Transylvania became to the Romans what Mexico afterwards was to Spain. Much of the gold that glittered on the tables of the wealthy patricians, or adorned the reigning beauties at the gladiatorial shows, was dug from the hills of Abrudbánya, or washed from the sands of the Aranyos and other streams. During the culminating epoch of Roman luxury, Transylvania was regarded as a vast treasure-house to be ransacked for wealth.

The old traveller Clarke (1818), alluding to the Wallachian Gipsies, says they are not an idle race; they ought rather to be described as a laborious people; and the majority honestly endeavour to earn a livelihood. It is this part of them who work as gold-washers. They have great skill in finding the metal. Their implements consist of a board 2 or 3 ft. wide, and 4 or 5 ft. long, with grooves cut transversely; and it is edged on both sides with a wooden rim: woollen cloths are sometimes spread upon this board, which being held as an inclined plane, the sands of the river are poured, mixed with water, upon it; the weightier sediment falls into the grooves, or it is retained by the cloth, which is afterwards washed in a water-cask; and then, by a common severing-trough, the sand is separated from the gold. But they are often skilful enough to collect auriferous pebbles, stamping them, and washing the powder. The surface of the plains consists of sand and pebbles, containing gold. Fig. 23 shows the Gipsies practising their art. Generally they sell the gold thus found, in the form of dust; but some of them, who have been accustomed to work as blacksmiths, have ingenuity enough to smelt the gold into small ingots, using for that purpose, little low furnaces, and blowing the fire by portable bellows, made of buckskin. The construction of these bellows is as simple as it is ancient: they are made by fixing an iron air-pipe into the skin of the neck of the animal, and by fastening 2 wooden handles to that part of it that covered the feet. Baron Born, describing the iron-works of the Wallachian Gipsies, cites a mineralogical writer of the name of

FIG. 23.



HUNGARIAN GIPSIES WASHING FOR GOLD.

Fridwalsky, who, in proving their antiquity, tells of an inscription found near Ostrow, relating to a *collegium frabrorum*, adding, that probably "the denomination of the Porta Ferrea, given to a pass on the Turkish frontier, is hence derived."

The officer of the Customs had a few of the ores of gold, from the Boitza mines; and particularly that extraordinary and rare association of the native gold with crystallized sulphuret of antimony, then peculiar to the mines in the neighbourhood of this place. The mountains of Boitza are connected with a chain that stretches on both sides of the river Maros, the Marisus of Strabo. From this place, as far as Deva, they consist of syenite-porphyry (the *saxum metalliferum* of Born), covered with limestone, slate, or sand. The principal mine of Boitza is worked in a variety of the syenite-porphyry, differing from the common variety, in having large pieces of felspar scattered through its substance. The uppermost gallery, when Baron Born visited these mines, was excavated in limestone, which is superincumbent on the porphyry; but the deeper gallery ran in sandstone, until it reached the argillaceous rocks. The veins and fissures consist of the sulphurets of zinc (blende) and lead (galena) containing both gold and silver. Some specimens exhibit the native gold, adhering, at the same time, to the zinc and to the lead. A cwt. of the ore of Boitza, after stamping, yields 8 lb. of metallic powder, containing 2 to 6 German oz. of silver; and, as all the silver of Transylvania and Hungary contains gold, that of Boitza averages 2 oz. of gold to every 1 lb. of silver.

A Wallachian, whose name was Arminian John, came to Clarke's father, then possessed of a rich silver-mine at Csertes, telling him that as he constantly observed a flame issuing from, and playing upon, a fissure in the Nagyag forests, he was of opinion that rich ores must be hid under ground. His father drove a gallery in the ground which the Wallachian had pointed out. The work went on some years without any success; but at last the adit hit the rich black and lamellated gold-ores, which were first looked upon as iron-pyrites.

Soon after, other fissures were discovered, all running parallel to each other, in the direction of the valley of Nagyag, from S. to N., and dipping from W. to E. The veins break off as soon as they reach the red slate with which all the valleys are covered. When Born visited Nagyag, the mine had only been worked to the depth of 60 fathoms: its depth is now 150. The mountains are entirely composed of porphyry, covered with red clay, or red argillaceous schist, and sandstone. The vein-rocks consist of red felspar and white quartz, of that kind which is vulgarly called "fat quartz." The richer ores are laminary, splendent, of a dark-grey colour, approaching to black, and in some instances quite black. The lamellæ may be separated with a needle; and they are malleable and ductile in a certain degree. There is also here found a very rich kind of ore, which is finely woven into the texture of a reddish felspar, resembling the arsenical white ore of Saxony. Among the rich ores, native silver sometimes occurs, mixed with gold. Another variety is called, by the miners, "cotton ore": it consists of little native silvery-gold grains, in tellurium, adhering to an argillaceous matrix.

But in all the richer ores (which are so productive of precious metal that the smallest particle being placed, with a little borax, upon the tube of a common tobacco-pipe, and submitted to the blow-pipe, becomes easily reduced to a bead of pure gold), not a particle of native gold can be discovered, even by the aid of the most powerful microscope. From the resemblance of its laminary form and splendent grey colour to antimony, it was at first considered as an ore of that metal; and for a long time, under the names of *aurum problematicum* and *aurum paradoxum*, it puzzled all the chemists of Europe. Sometimes an effect of crystallization has given to this laminary substance a rude resemblance of Hebrew characters; and to such appearances the name *aurum graphicum* was given. When Klaproth detected, in the analysis of this ore, the presence of a new metal, and bestowed upon it the name of tellurium, its real nature became more fully developed.

The Gipsies of the Bannat get their livelihood, like those of Wallachia, by rambling about as blacksmiths and musicians. In winter, they cut spoons, ladles, troughs, and other implements of wood. During summer they go nearly naked, and are then employed in washing gold from the sand of the rivers and plains. Their manipulation has been fully described by Francis Dembsher, in an appendix to the Letters of Born to Ferber: its very simplicity denotes its antiquity; and it is probably practised now, by these Gipsies, as it was by the Romans in the same country. It consists in nothing more than pouring the sand, mixed with water, over an inclined plane, the heavier particles of the gold remaining upon the surface, while the lighter siliceous particles and impurities are washed away. This, in fact, is the plan pursued in the great washing-houses at Schemnitz, only upon a larger scale. Sometimes the inclined plane is covered with woollen cloth, to which the gold adheres: wanting the cloth, the Gipsies now and then use, for the same purpose, the more ancient substitute of a fleece. The manner of collecting gold-dust in sheep's fleeces, upon inclined planes, is represented in the curious old work of Agricola.

In the rivers of Colchis, the custom is still retained of placing sheep-skins in the beds of the Phasis, and other auriferous streams, to collect particles of gold: hence the dedication of such fleeces to the Gods, and the fabulous history of the Argonautæ as far as it related to the golden fleece. The more common manipulation among the Gipsies of the Bannat is very like that of Wallachia, already described. It is performed by means of a plank of lime-tree, 6 ft. in length and 1½ in. in thickness. At the upper extremity, is a small trough; and across the board, are 10 or 12 grooves or furrows cut in the wood. This plank is elevated at one end, at an angle of about 45°. The sand is put into the trough, at the upper end; and thence, by plenty of water, washed down the sloping of the board. The gold-dust falls, during this process, into the higher grooves, whence it is scraped or brushed off. It might be supposed that a great deal of gold is lost by this careless method of collecting it; but long experience has made the Gipsies very expert: they know how to distinguish the richer from the poorer sands; and a careful examination of the sand, after they have washed it, proves that hardly a particle of gold escapes them during the operation. The families supported by gold-washing are very numerous; but the gains of each are very inconsiderable, being barely sufficient to excite their industry, although the value of many thousands of florins of gold be annually produced in this manner. The auriferous sand is not only taken from the beds of the rivers, but likewise from the banks, and even from pits in the adjacent ground. These pits are commonly 4 ft. or more in depth. In digging them, the workmen find 4 strata. The first is a stratum of vegetable mould; the second, loam, and an alluvial deposit of pebbles; the third consists of the auriferous sand and pebbles; and the fourth of slate, clay, marl, and coal. The auriferous stratum is constantly parallel to the bed of vegetable mould, and the coal as constantly lies below it. The gold obtained by washing is always native, and in the form of a fine dust; the sand containing it is also mixed with black and splendent particles of highly magnetic iron, garnets, and mica.

The inhabitants consider their mine of Bakabánya as ranking next in importance to those of Cremnitz, not only for the gold it annually yields, but also for the silver. In the tellurium mine at Nagyag, occur some instances where the ores of gold do not contain silver; otherwise it might be stated as a general observation, applying to all the mines, whether of the north of Hungary, of the Bannat, or of Transylvania, that every ore containing gold, contains also a certain portion of silver. This was also stated by Prof. Passern at Schemnitz, and by others acquainted with Hungarian mines, as an observation admitting of no exception. And every mineral considered as an ore of silver, however pure the silver may appear, is also said to contain gold; even the richest sulphurets of that metal, called vitreous and ductile silver-ore.

The ore dug here consists of clay and ochreous quartz. It is richer in gold than that of any other mine in all Hungary; but it does not hence follow that this is the most productive mine. Owing to the rich quality of the Bakabánya ores, they have a method of estimating their value which reverses the method of calculation used at Schemnitz. The ores of the latter are called silver-ores, those of the former, gold-ores. The miners of Schemnitz calculate that one *mark* of their silver contains so many *derniers* of gold: those at Bakabánya, that a certain weight of their gold contains so many *lotos* of silver. The mountain itself is an abutment of argillaceous schist, dipping into the great plain which extends towards Tyrnaw, and to the Danube.

Cremnitz is the oldest mining town in all Hungary. Clarke was conducted to the vein of gold-ore in the principal mine, by levels kept everywhere clean and dry. The miners were then employed in digging this ore; and had laid open a very rich part of it. It consisted of white quartz, containing auriferous silver-ore, and auriferous pyrites. The latter, when properly stamped and washed, yielded 2 to 3 drachms of gold in the hundred. The direction of the vein was N. and S., being at the same time inclined from the W. towards the E., according to an angle which varies from 25° to 30° and 40°. Like many of the Hungarian auriferous ores, this consists of clay, quartz, galena, and the oxide of iron, traversing a porphyritic rock beneath a stratum of slate.

There are several mines at Cremnitz, some belonging to individuals, others to the Crown. Cremnitz is the oldest of all the towns where there are mines: and of the 7 famous mining districts—those of Schemnitz, Cremnitz, Neusohl, Königsberg, Bakabánya, Libeten, and Tilu—Cremnitz, although not the most abundant in precious ore, is said to be the richest. Its deepest mine has been worked to the depth of 300 fathoms.

All the metallic veins of Schemnitz extend N. and S., their inclination or dip being from W. to E., at an angle of about 60°. They run parallel to each other. The principal veins are 6 in number; but there are many smaller ramifications from these, which often prove very rich. The [illegible] house or lavatory for the ores consists of a series of washing-[illegible]ns, ranged one below another, from the roof to the floor of the building, having iron sieves at the bottom, increasing in the width and coarseness of their texture, from the lower to the higher sieve; the highest sieve is wide enough to let stones of a certain size pass through, while through the lower sieves nothing passes but gravel, and ultimately nothing but sand. A wheelbarrow, filled with the waste of the mines, is emptied into the upper trough and there washed. All the stones that do not pass through the first sieve are then taken to the first table to be examined, and the ores picked out; those that are caught by the second sieve, to the second table; and so on with the rest. In this manner, an immense quantity of discarded ores, that were cast away when mines were less economically worked, are recovered and prepared for smelting. But the sand which ultimately escapes through the lower sieve is directed with the streams of water through channels, until it is made to fall over inclined planes covered with woollen cloths; and thus a very considerable quantity of wash-gold is arrested in its progress by the cloths, in the same manner that the Gipsies of Transylvania and Wallachia obtain gold-dust, by washing the sands of their rivers.

Salzburg.—The gold produced in Gastein and Rauris formerly possessed some importance, and Noric gold was known to the Romans. The industry reached its maximum in 1460–1560, when the yearly yield is supposed to have been about 4000 *marks* (2472 lb.) gold and 8000 *marks* (4944 lb.) silver, in Gastein alone. At Rauris, the gold occurs in quartz veins traversing gneissic rocks. It averages 8 dwt. per ton. Formerly, there were gold-washings in the Siechenbach and Salzach, and many other streams in Salzburg, enumerated by Posepny, which yielded, in 1600–99, 18,977 lb. of gold; and in 1700–96, 38,480 lb.; total, 57,457 lb.

Styria.—According to Strabo (bk. v. c. i. § 8: Bohn's library, i. 319), the country of the Heneti was bounded by a river which flows from the Alps, and is navigable for a distance of 1200 *stadia*, as far as the city of Noreia (the modern Friesach in Styria). This place contains five stations for gold-washings.

Tyrol.—The Tyrolese gold-workings are at Zell, in the Zillerthal. The metal occurs in quartz veins, traversing chiefly clay-slate, and is present in the proportion of about 9 dwt. per ton.

FRANCE.—Peuchet (1805) says that there are no valuable gold-mines in France, but that certain streams roll down grains of gold 18 to 22 carats fine, e. g. the Rhine, Rhône, Doubs, Cèze, Gardon, Ariége, Garonne, Salat, and Tarn. This gold cannot be taken into account in estimating the national wealth, but gives a profit to those who wash the sands for it.

Debombourg (1868) gives the following details of gold in France. It is found chiefly in the Alps, the Pyrenees, and the Cevennes; and the water-courses from these mountains are constantly bringing down particles of the precious metal, disaggregated from the rocks. Probably there does not exist in the whole country more than one real vein of gold, that in La Gardette (Isère), discovered in 1700, and worked, up to 1841, at an expense infinitely greater than the produce. The principal gold-bearing rivers of the Alps are the Rhine, the Rhône, and the Arve; of the Pyrenees, the Ariége, the Garonne, and the Salat; of the Cevennes, the Ardèche, the Cèze, the Gardon, and the Hérault. The Rhône brings down not only gold-dust but nuggets, as it did even in the Celtic period, when the inhabitants found the shining metal on the river-banks amongst the sand and pebbles. The auriferous wealth of that river preserved its importance for a long period, and gave rise to a branch of industry called that of the "Orpailleurs," those engaged in which the edicts of Louis XI. and Louis XIV. term "Cueilleurs de paillettes d'or." There were orpailleurs at Rache-de-Glun, La Voulte, St. Pierre-de-Bœuf, Condrieu, Givors, and Mirabel. In the Michaille and a part of the Gex district, the people were accustomed, when the water was low, to seek gold-particles on the banks, where they usually found them with little trouble. In 1809, a field labourer at Tronquoy, near St. Quentin, struck with his ploughshare a large mineral mass which he thought was iron. He took it home, where for 20 years it served as a support to his *pot-au-feu*, in the fire-place. One day he discovered some yellow streaks in it, and he said to himself they might possibly be copper. A coppersmith, to whom he sold it for 2 francs, could never succeed in melting it, and at last he took the mass back to the peasant from whom he had bought it. A dispute arose, which the Juge de Paix directed to be decided by an expert in chemistry. The latter declared that the article which the seller would not receive back was pure gold, and worth 30,000 francs. The buyer thereupon reclaimed his property, but the other contested the claim, and the case subsequently went before the Civil Tribunal, which awarded the nugget to the finder.

Engelhardt observes that Julius Cæsar found the inhabitants of Gaul possessed of great wealth, and in the time of Augustus it paid considerable quantities of gold into the Roman treasury.

Strabo (bk. iv. c. i. § 13 : Bohn's library, i. 279) says "the Tectosages dwell near to the Pyrenees, bordering for a small space the N. side of the Cevennes [between Lodéve and Toulouse; it must be remembered that Strabo supposed the chain of the Cevennes to run W. and E.]; the land they inhabit is rich in gold."

And again (bk. iv. c. ii. § 1 : Bohn, i. 283–4), "Here is the gulf which, with that on the coast of Narbonne, forms the isthmus. Both these gulfs (of Gascony and Lyons) go by the name of the Galatic gulf. The former gulf belongs to the Tarbelli [who occupied the sea-coast from the Pyrenees to the Lake of Arcachon]. These people possess the richest gold-mines ; masses of gold as big as the fist can contain, and requiring hardly any purifying, being found in diggings scarcely beneath the surface of the earth, the remainder consisting of dust and lumps, which likewise require but little working."

In his history of Rumilly, F. Croisollet records that about the year 1770 a gold-seeker named Cocrair met with his death in the cavern which bears his name, and which is situated at 6 kilomètres (3¾ miles) W. of Rumilly, on the territory of Moye, and on the flanks of Mont-Clairgeon (Haute-Savoie). A stream, on whose banks the sand is mixed with grains of gold, traverses the bottom of this cavern at a depth of about 33 mètres (18 fathoms). This auriferous sand was the aim of the unfortunate man's repeated descents into the cavern, which ultimately resulted in his being entombed there. The gold-washing seems to have been neglected ever since; but the cavern was visited by a party from the Alpine Club of Rumilly on August 20 and 21, 1875, and an account published by A. E. Gallet.

GERMANY.—Dr. Soetbeer gives the following figures concerning the gold-production of Germany:—

	lb.		lb.		lb.
1849 ..	5·72	1859 ..	45·10	1868 ..	253·22
1850 ..	8·36	1860 ..	94·60	1869 ..	173·80
1851 ..	20·68	1861 ..	62·70	1870 ..	149·82
1852 ..	29·92	1862 ..	21·56	1871 ..	181·06
1853 ..	42·90	1863 ..	101·20	1872 ..	720·50
1854 ..	28·38	1864 ..	92·62	1873 ..	639·00
1855 ..	34·54	1865 ..	77·88	1874 ..	803·22
1856 ..	19·14	1866 ..	231·22	1875 ..	731·06
1857 ..	32·34	1867 ..	186·56	1876 ..	618·86
1858 ..	33·44				

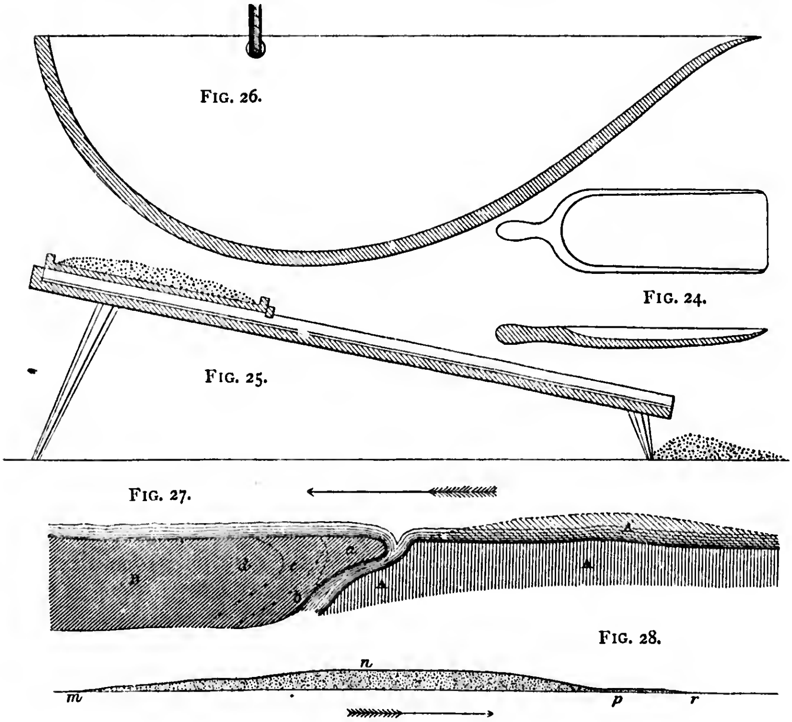
The gold occurs in the lead- and copper-ores in very minute quantities. In 1866, the auriferous ore raised amounted to 310,133 lb., value 141,791 *thalers*; of this, 66 lb. came from Hanover, 9630 lb. from Prussia and Brunswick, and 234,502 lb. from Saxony. The lead-mines of Wiesbaden gave 157·461 lb. of gold in 1874, and 202·425 lb. in 1875. Clausthal gold in the same year was 64·479 lb. from Lautenthaler, 40·394 lb. from the Altenhauer Hütte, and 22·975 lb. from Halle. The Oberharz raised 257·186 lb. of gold in 1874, and 116·405 lb. in 1875.

The gold produced in Prussia, which is a very small quantity, is obtained by an interesting process invented by Güttler, of Reichenstein, in Silesia. He impregnates the peroxide of iron, obtained in roasting the arsenical gravel, with chlorine gas, extracts it with water, and precipitates the gold with hydrosulphuric gas. The precipitate of sulphide of gold is roasted, again extracted with hydrochloric acid, and smelted with borax and saltpetre. Güttler obtained in 1859 a mining licence for the whole district of auriferous sand in Lower Silesia, at Goldberg and Löwenberg, where, in the ninth and tenth centuries, gold-mining was in a flourishing condition. This auriferous sand contains only a small quantity of gold,—0·0016 per cent.—but extends over some 20 German sq. miles.

The Rhine.—The Rhine is notoriously auriferous in Baden, Bavaria, and part of France. Several essays have been written upon it, the latest and most complete being Daubrée's (1846), from which the following notes are condensed in translation.

Between Bâle and Bingen, the Rhine winds through a wide deposit of gravel, composed of very various rock-débris, part of which appears to come from the Vosges and Black Forest, but a large part, including the schistose quartz, is of alpine origin, while some is from the Jura, and a little from the volcanic Kaiserstuhl. Gold is exploited in some parts of the Upper Rhine, above Constance, as between Coire and Mayenfeld; in the neighbourhood of Waldhut, not far from the confluence of the Aar, the metal has been extracted from the bed of the river at various times; but it is especially from Bâle to Mannheim, a distance of some 150 miles, that the Rhine is regularly auriferous. Thurneisser also cites Mayence as one of the places where gold-washing was conducted. In the vicinity of Istein, then in the neighbourhood of Nieffern on the left bank, and of Petit-Kembs and Rheinwiller on the right, gold-washers are met with at intervals. Near Nambseim, Geisswasser, and Vieux-Brisach, the gravel is sometimes quite rich, but very irregularly so. It is chiefly lower down, about 62 miles from Bâle, that the workings have always been numerous, and they are particularly concentrated from a few kilomètres above Kehl, to Daxland, near Carlsruhe.

The washers make a preliminary test of the gravel by rudely panning



RHINE GOLD-DEPOSITS AND WASHING APPARATUS.

a sample, and if they find as many as 10 or 12 "colours" in this way, they reckon to earn about 1½ *fr.* (15*d.*) by their day's labour. The method of panning has nothing singular about it; the instrument used is made of wood, charred black on the inside to facilitate discovery of the gold-grains, and of the shape indicated in Fig. 24, measuring about 16½ in. in total length, 4½ in. in width at the mouth, and ½ in. deep in the dish. The apparatus employed in washing the gravel has not varied from that described by Heberer in 1582, and illustrated in Fig. 25. It consists of an inclined table about 2 yd. long and 1 yd. wide, covered with a cloth made of long-stapled wool, set at an angle of 10° to 12°. At the head of the table is a sieve or hurdle made of osiers, the orifices in which are not more than ¾ in. in diameter; when this is filled with gravel, the operator washes it with water from a hand-bucket till all the smaller material has passed through the interstices, leaving the stones exceeding ¾ in. in diameter, which are then thrown out. The fine sand and gold-grains remain for the most part caught in the wool, while the stones either roll away at once or are brushed out. When this has been done several times, the blanket is removed from the table and washed in a tub of clean water, by which the sand and gold-grains are dislodged from the fabric. This mixture of sand and gold is generally carried home to be separated, which is effected in the wooden boat-like vessel, termed a *Schiff* in Seltz and a *Sass* in Baden, shown in Fig. 26, and measuring about 4 ft. 6 in. long and 1 ft. 6 in. deep.

The cloth used on the table is that known locally as *drap de Souabe* or *Schwabentuch*, and is the same as the Tyrolese and the German waggoners used for cloaks. It endures about 1 year, if turned when the first side is worn out. The grains of gold are driven with some force by the water into the meshes of the cloth, and sometimes even completely through, in which case they are arrested by a second cloth of cotton or linen, on which the blanket rests. This duplicate cloth is only necessary below the hurdle: the greater part of the gold stops at the lower edge of the grating. A man working 12 hours a day can treat about 4 cub. yd. in this manner. About 10 per cent. of the gold is lost in ordinary gravel at this stage; it might be diminished by reducing the angle of the table, but that would also lower the daily outturn. The gold collected subsequently in the *Schiff* is amalgamated with about ¼ its weight of mercury.

With regard to the distribution of the metal in the gravel banks, this follows certain rules which appear to be well understood by the gold-washers. (1) The most highly auriferous spots, termed *Goldgründe*, are those formed by the re-distribution of gravel banks or islands, as indicated in Fig. 27, thus: A is a bank of poor gravel, the portion A′ of which has been carried away by the stream and formed into a bank B, whose richest spots will be *a b c*, the gold always being found where the largest and heaviest stones have rested. (2) Spots behind artificial obstructions in the river are often rich. (3) Banks re-formed in the middle of the river far from their source are generally poor. (4) Sometimes in the poorest deposits occur comparatively rich strips, due to local rearrangement after or during the formation, occupying the down-stream edge of the bank, as shown in Fig. 26 : *m n p* is a poor bank, terminating in a rich patch at *p r*, just above the water-line. (5) Not a trace of gold can be found in the fine sand. The proportion of gold is greater according as the river has fallen more slowly. According to Daubrée's researches the maximum and minimum gold-yield may be stated thus:—

Quantity of Gravel.	Depth of Deposit.	Volume washed per 9 hours.	Weight of Gravel.	Yield of Auriferous Sand.	Gold in 1 cub. ft.	Yield of Gold.	Value of Gold per 9 hours' work.
	in.	cub. ft.	lb.	lb.	gr.	gr.	*s.* *d.*
First	5·85	121	13,662	22	53·85	15·59	8 9
Second	2·73	118	13,205	21	22·68	6·75	3 7
Third (average worked) ..	3·51	114	12,826	15	11·72	3·61	2 0
Fourth (poorest worked) ..	10·92	109	12,236	2¾	0·61	0·22	0 1¼

The gravel at *d*, Fig. 27, is no longer payably auriferous.

It is not only in the bed of the Rhine, that gold is met with; it occurs in the gravel at various points distant 5 or 6 miles from the stream, and appears to be generally disseminated throughout all the alpine gravel constituting the plain of the Rhine, as well as in the ancient alluvions of the river, and in those of the Ill, which are similar. But the proportions are too small to admit of working at a profit by existing means.

The average assay of the Rhine gold is 0·934 gold and 0·066 silver. Döbereiner found 0·00069 of platinum. Daubrée estimates the total production at 40,000 to 45,000 *fr.* (1583*l.* to 1786*l.*) per annum, divided among about 500 gold-washers.

GREECE.—The islands in which the Greeks carried on gold-mining operations included Thasos, Cyprus, and Siphnos [Siphanto]; to these, Tournefort adds Naxos, stating that the natives "pretended" that gold- and silver-mines existed near the castle of Naxia. Rawlinson (Herodotus, ii. 57: Thalia, iii. 57) says that lead was still abundant in Siphanto in the time of Tournefort, but the gold- and silver-mines had failed before the time of Pausanias. The words of Pausanias (bk. x. c. xi. : vol. iii. pp. 115–6) are, "The island Siphnos had gold-mines; and they were ordered by Apollo to send a tenth of the produce of these mines to Delphos; in consequence of which they built a treasury, and sent with it a tenth of the produce of their mines. Afterwards, however, through their immoderate desire of accumulating wealth, they neglected to send the tenth of their riches to Delphos; and in consequence of this their gold-mines were destroyed by an inundation of the sea." Laurent (Herodotus,

i. 225: Thalia, iii. 57) says, "The affairs of the Siphnians about this time were in the most flourishing state: they were the richest of the islanders; having in their island, mines of gold and silver, so productive, that out of the tithe of the coin accruing from them a treasury is dedicated at Delphi, comparable to the richest. They divided among themselves, every year, the product of these mines."

Col. Leake says that Belon, who visited the mines of Sidherokápsa in the middle of the sixteenth century, asserts that he found 500 or 600 furnaces in different parts of the mountain, that besides silver, gold was extracted here from pyrites, that 6000 workmen were then employed and that the mines sometimes returned to the Turkish Government a monthly profit of 30,000 ducats of gold.

ICELAND.—The suspected occurrence of gold in Iceland is thus alluded to by the editor of the present work in a previous volume on that island. "A lump of mineral carelessly gathered by one of the members of our expedition on the brink of the Kettle crater, showed, on analysis by Mr. White, of Finsbury, the following composition:—

Silver	..	..	14 oz. 14 dwt. per ton of mineral.
Gold	..	..	0 ,, 9·19 ,, ,,

"The mineral was a brownish-black coloured, vesicular, cindery, easily powdered mass, and was generally supposed to be a sample of palagonite conglomerate, which had been subjected to great heat subsequently to its deposition. In the crevices and cavities of the mass, the precious metals were found native."

Unfortunately, diligent search failed to procure a second specimen, which is the more to be regretted, as it leaves a doubt resting over the genuineness of the first, while if duly authenticated, it would be evidence of the actual formation of the metal within almost historical times.

ITALY.—According to Strabo (bk. iv. c. vi. § 7: Bohn's library, i. 305), the country of the Salassi (in ancient Gallia Transpadana, in modern Piedmont) contains gold-mines, of which formerly, in the days of their power, they were masters, as well as of the passes. The river Doria Baltea (ancient name Duria) afforded them great facility in obtaining the metal by supplying them with water for washing the gold, and they have emptied the main bed by the numerous trenches cut for drawing the water to different places. This operation, though advantageous in gold-hunting, was injurious to the agriculturists below, as it deprived them of the irrigation of a river, which, by the height of its position, was capable of watering their plains. This gave rise to frequent wars between the two nations; when the Romans gained the dominion, the Salassi lost both their gold-works and their country; but as they still possessed the mountains, they continued to sell water to the public contractors of the gold-mines, with whom there were continual disputes, on account of the avarice of the contractors, and thus the Roman generals sent into the country were ever able to find a pretext for commencing war.

Again (bk. v. c. i. § 12 : Bohn, i. 325) he says the mines of Cisalpine Gàul (which included modern Piedmont and Lombardy) are not worked now so diligently, because not equally profitable with those of Transalpine Keltica and Iberia; but formerly they must have been, since there were gold-diggings even in Vercelli, near to Ictimuli [probably Victimolo], both which villages are near to Placentia [Piacenza]. And (bk. v. c. iv. § 9 : Bohn, i. 368), Pithecussæ [Ischia] was very prosperous, on account of the fertility of the soil and the productive gold-mines.

Pliny (bk. iii. c. 24 : Bohn's library, i. 257) declares that in abundance of metals of every kind, Italy yields to no land whatever; but all search for them has been prohibited by an ancient decree of the senate, who gave orders thereby that Italy shall be exempted from such treatment. But it is difficult to say what is the exact force of "*parci*" here; whether in fact it means that Italy shall be wholly exempted from such treatment, as an indignity offered to her soil, or whether her minerals were to be strictly kept in reserve as a last resource : Ajasson, in his translation, seems to take the former view ; Littré, the latter.

According to Giulio Axerio, the mountains of Valsesia and Ossola yield gold. The precious metal is found in auriferous iron-pyrites, in the native state, in quartz, and also associated with copper-ore. By washing the solid residuum of river and mountain torrents, sufficient is produced annually to prove that "golden sands" are not quite a fable. About 60,000*l.* represents the annual value of the gold of Italy, which is extracted by the amalgamation process.

Capt. Smyth (1828), alluding to the tradition of gold in Sardinia, explains the name Luogo d'Oro as a corruption of Luogo Doria. But the argentiferous galena mines are renowned, and probably some gold is extracted from these ores.

Hartmann, in 1860, placed the yearly gold-production of Italy at about 220 lb.; Roswag made it 418 lb. In 1868, the official estimate of the gold-yield of Monte Rosa and Corsente was about 94½ lb. A British Consular Report for 1877 states the value of the gold extracted at 257,400 *lire* (10,188*l.* 15*s.*), and of iron-pyrites, 78,520 *lire* (3108*l.*).

Through the very kind instrumentality of Commander Felix Giorolano, Chief Director of the metallic mines of the kingdom, the author has been furnished with a special report on the gold-workings of Italy in 1882, illustrated by the accompanying sketch-map, Fig. 29, which may be translated as follows.

Gold-veins exist in several localities in northern Italy, especially in the W. Alps, in the neighbourhood of the Simplon, Monte Rosa, and

Mont Blanc, as well as at several points in the Ligurian Apennines, N. and N.E. of Genoa. But these veins are of no great richness, their total yield having rarely exceeded 2 lb. of gold daily, and being generally below that figure. The most extensively worked veins are in the before-mentioned groups of the W. Alps, especially in the valleys descending from Monte Rosa and the Simplon towards the E. into the basin of the Toce, and thence into the Lago Maggiore. They are the valleys of Antigorio, Antrona, Anzasca, and Toppa or Marmazza. Also at Alagna, at the head of the valley of the Sesia, on the S. foot of Monte Rosa.

FIG. 29.

SKETCH-MAP OF ITALIAN GOLD-FIELDS.

The veins in these valleys consist of numerous threads of iron-pyrites and quartz, traversing quartzites and mica-schists passing into gneiss. Their general direction is N. and S., or N.N.W. and S.S.E. The gold is usually disseminated invisibly in the iron-pyrites, and is rarely to be seen in tiny grains in the white quartz, as in some of the veins in the Val Toppa. The ores accompanying the auriferous pyrites are copper-pyrites, mispickel [arsenical pyrites], grey copper-ore, galena, and blende. Their proportions vary with the locality : sometimes the mispickel is very abundant, as in the mine called Cani, the ore from which is treated at the Battigio works, Valle Anzasca.

Occasionally, native gold is found in the beds of copper-pyrites at Ollomont, in the valley of Aosta, but in very small isolated patches of no permanence, while the veins of the Monte Rosa valleys, however variable in richness, have a certain continuity. The gold-yield of the pyritous ores is not commonly very high. The richest reaches $2\frac{1}{2}$ to 3 oz. per ton, but $1\frac{1}{2}$ oz. is considered a high figure, and it often descends to 13 dwt. or less. It is sometimes worked at a profit when even lower than this. The gold gained by amalgamation contains about 25 per cent. of silver.

The veins have been an object of exploitation for a very long time. Formerly, the Government itself worked some mines, as those of Alagna, in the valley of the Sesia, where is a group of very interesting veins; but it has generally been left to private enterprise. According to the mining laws of Upper Italy, mines, being considered *res nullius*, are the object of concessions, granted gratis by the Government to those willing to take them, precedence being given to the discoverer. More than 60 localities are known where operations have been undertaken, generally on Government concessions; but a great part have been abandoned. There remain about 26 concessions in force, but the number of mines actually at work is not more than 5 or 6.

As a rule, in former days, operations were conducted on a very modest scale. The ore was first pounded under stamps, then amalgamated with mercury in little mills established on the water-courses of the neighbouring valleys, and capable of treating 120 to 132 lb. of pyrites per 24 hours. But at Pestarena, in the Valle Anzasca, was a considerable undertaking, with an adit cutting several veins, and a works of some importance.

During the last 20 years, the small isolated exploitations have given place to larger works by their combination. Two English companies have acquired these rights and conducted operations on a grand scale with improved means. The Pestarena United Gold-mining Co. (Taylor & Co.) took the mines of Valle Anzasca and Val Toppa, with their reduction-works at Macugnaga, Pestarena, Battigio, and Fomarco, at the Pié-di-Mulera. The other, called the Val Antigorio Gold-mining Co., took those in the valleys farther E., with the works at Crodo. These companies have established wire-rope tramways for the economic transport of the ore across the valleys and spurs to the works. The latter are provided with powerful crushing apparatus and mills, capable of treating 1100 to 1320 lb. of ore per diem.

The production of these mines has nevertheless always been very modest. The official statistics of the resident engineers, perhaps a little below the mark, but always sufficiently near, for many years past show a mean total rarely exceeding 440 lb. annually of gold of 75 per cent. fineness, and sometimes less than that. Since the operations of the two before-mentioned English companies, the production has increased a little; $2\frac{1}{4}$ to $3\frac{1}{3}$ lb. daily has been spoken of, but even that has not been continuous, and an annual yield of 660 lb. seems to have been seldom reached. Meantime some mines have been abandoned, as that of Cani, with the works at Battigio, in 1875; the Antigorio Co. has closed the Crodo works, and a part of its territory has passed to the Pestarena Co., which continues working on a mediocre scale. It nevertheless would seem not a bad enterprise to resuscitate the mines of Alagna.

In a valley of the Ligurian Apennines called Val Corsente, between Alexandria and Genoa, in the arrondissement of Novi, exists a group of auriferous quartz veins traversing serpentine rocks, which have been experimentally worked. A reduction-works has been erected at Casaleggio, near the said valley; but the production of this locality has always been very trifling, and operations are now suspended. Mention may also be made, though rather as a matter of curiosity, of some nuggets of crystallized native gold found some years since in the copper-pyrites mine of Monte Loreto, above Sestri-Levante (E. Ligurian Riviera). One of these nuggets weighed several lb., but it was quite of isolated occurrence, and similar finds have not recurred.

In Upper Italy, gold is also found in the form of small grains and spangles in the ancient alluvions covering the foot of the W. Alps, where exist the veins already described. They are, especially the valleys of the Orco, the Dora-Baltea (valley of Aosta), the Sesia, and the Ticino, descending from the Graian and Pennine Alps, which possess auriferous alluvions. There are reasons for believing that the ancient or deep alluvion, which is found beneath the level of this part of the valley of the Po, at the foot of the W. Alps, is in places rich in gold. There exist historic traditions leading to the conclusion that at the time of the Roman Empire, considerable works were here carried on. In the plain stretching E. of the Dora-Baltea are traces of these operations, even adits driven in the alluvion. An ancient document speaks of thousands of workmen (slaves) who mined gold in these regions. But to-day there is not a single work in progress.

There exist also alluvions of some importance in the before-mentioned valley of the Corsente, and in that of the Orba, which receives this torrent: alluvions which bear also evidences of ancient work; but their riches, which seem sufficiently small, do not encourage modern enterprise.

Alluvions containing metalliferous sands belong in Piedmont to the owner of the soil. As to the beds of rivers, permission is given to search and wash the sands, under regulations for preventing damage to the public water-supply. At present, however, no undertaking of importance is on foot. A few individuals only, armed with a wooden bowl, occasionally wash the sands of the before-named Alpine rivers, extracting a meagre return, the total annual value not exceeding a few thousand francs.

ROUMANIA.—Gold is found in most of the rivers flowing from the Carpathians, but chiefly in the Olto and Ardgèche and their tributaries. These placers were formerly worked by state slaves, and the proceeds belonged to the reigning princesses. Vein-gold is found in the mountains of Ardgèche, Rucar, Tergoviste, Bacau, Niamtzo, and Suciara. Some very coarse alluvial gold from Roumania was shown at the Paris Exhibition of 1867.

RUSSIA IN EUROPE.—In 1874, gold-washing was begun on the tributaries of the Tana, in the district of Uleaborg, where 400 lb. of the precious metal was obtained in the following year, the process employed being modelled after the Californian sluices. The country where the gold was obtained forms part of Russian Lapland, between the 70th parallel and the Arctic Circle, a region unsuited by climate and nature for the development of mining industry, and difficult of access, owing to the want of roads, from the towns of Torneä and Kola, about equidistant from the placers. At first, experiments were made for transporting supplies to the prospecting parties of gold-seekers by means of reindeer, but these were found too costly. Whenever diggings were opened on the Tana and Ivalo, the yield proved disappointing; while in Finland (see p. 724) the search was altogether unsuccessful. It is, however, premature to conclude that rich deposits of gold are not contained in Finland and Lapland, which may be only awaiting a fortunate, or perhaps a more experienced, discoverer.

Where the granites of Finland border on the governments of Archangel and Olonetz, they are associated with crystalline schists, and these probably contain gold. In the district of Kem, at Voitsk, on the Vyg, a river flowing through Lake Vyg before emptying into the White Sea, auriferous quartz was found in veins crossing the talcose schists. But the attempts to work the mine, though repeated for several years, failed, and in the end it was abandoned, in 1794, after having produced 169 lb. of the precious metal. This was the earliest of the gold discoveries in Russia.

In the Olonetz government the search for gold has been hitherto unsuccessful, notwithstanding the extensive crystalline azoic formations which should contain gold; and the same may be said of Kola, the borders of the governments of Archangel and Olonetz with Finland, the Timan range, Cape Kanin, the Kalguief Islands, Vaigatch and Nova Zembla, among the least visited parts of the solitudes of Northern Russia. The granites of Olonetz lie generally in a north-east and south-west direction, parallel with the water-parting of the rivers flowing into the Baltic and Arctic seas.

SERVIA.—According to Paton (1845), the lessees of the gold- and silver-mines of Servia, as well as the workmen of the State mint, were Venetians.

SPAIN.—According to Strabo (bk. iii. c. ii. § 3, 8: Bohn's library, i. 214, 219–20), there are copper and gold about the Cotinæ [Cotillas, or perhaps Constantina, near Almaden]. These mountains are on the left as you sail up the river Guadalquiver. Turdetania is intersected by the Guadalquiver, and contains the towns of Cordova in Andalusia, Cadiz, and Seville. It abounds in metals. Gold is not only dug from the mines, but likewise collected, sand containing gold being washed down by the rivers and torrents. It is frequently met with in arid districts, but here the gold is not visible to the sight, whereas in those which are overflowed the grains of gold are seen glittering. On this account, they cause water to flow over the arid places in order to make the grains shine; they also dig pits, and make use of other contrivances for washing the sand, and separating the gold from it; so that at the present day more gold is procured by washing than by digging it from the mines. The Galatæ affirm that the mines along the Kemmenus mountains [Cevennes] and their side of the Pyrenees are superior; but most people prefer those on this side. They say that sometimes amongst the grains of gold lumps have been found weighing ½ lb.: these they call *palæ*; they need but little refining They also say that in splitting open stones they find small lumps resembling paps. In the beds of the rivers, the sand is either collected and washed in boats close by, or else a pit is dug to which the earth is carried and there washed. Certain of the copper-mines are called gold-mines, which would seem to show that formerly gold was dug from them.

Pliny (bk. xxxiii. c. 21: Bohn's library, vi. 99–104) gives a more detailed account. According to him, "gold is found in our own part of the world; not to mention the gold extracted from the earth in India by the ants, and in Scythia by the griffins. Among us, it is procured in three different ways; the first of which is, in the shape of dust, found in running streams, the Tagus in Spain for instance, the Padus in Italy, the Hebrus in Thracia, the Pactolus in Asia, and the Ganges in India; indeed, there is no gold found in a more perfect state than this, thoroughly polished as it is by the continual attrition of the current.

"A second mode of obtaining gold is by sinking shafts or seeking it among the débris of mountains; both of which methods it will be as well to describe. The persons in search of gold in the first place remove the *segutilum*" (Ajasson remarks that the Castilians still call the surface earth of auriferous deposits by the name of *segullo*), "such being the name of the earth which gives indication of the presence of gold. This done, a bed is made, the sand of which is washed, and, according to the residue found after washing, a conjecture is formed as to the richness of the vein. Sometimes, indeed, gold is found at once in the surface earth, a success, however, but rarely experienced. Recently, for instance, in the reign of Nero, a vein was discovered in Dalmatia, which yielded daily as much as 50 lb. weight of gold. The gold that is thus found in the surface crust is known as *talutium*, in cases where there is auriferous earth beneath. The mountains of Spain" (we learn from Ajasson that numerous pits or shafts are still to be seen in Spain, from which the Romans extracted gold. At Riotinto, he says, there are several of them), "in other respects arid and sterile, and productive of nothing whatever, are thus constrained by man to be fertile, in supplying him with this precious commodity.

"The gold that is extracted from shafts is known by some persons as *canalicium*, and by others as *canaliense*" (both meaning "channel-gold"); "it is found adhering to the gritty crust of marble" (*marmoris glareæ*, under which name he no doubt means quartz and schist), "and altogether different from the form in which it sparkles in the sapphirus of the East, and in the stone of Thebais and other gems, it is seen interlaced with the molecules of the marble. The channels of these veins are found running in various directions along the sides of the shafts, and hence the name of the gold they yield—*canalicium*" (channel-gold or trench-gold). "In these shafts, too, the superincumbent earth is kept from falling in by means of wooden pillars. The substance that is extracted is first broken up, and then washed; after which it is subjected to the action of fire, and ground to a fine powder. This powder is known as *apitascudes*.

"The third method of obtaining gold is by the aid of galleries driven to a long distance; . . . these mines are known as *arrugiæ*" (deep mines in Spain are still called *arrugia*, a term also used to signify gold beneath the surface); . . . "in this kind of mining, arches are left at frequent intervals for the purpose of supporting the weight of the mountain above. In mining either by shaft or by gallery, barriers of silex are met with, which have to be driven asunder by the aid of fire and vinegar; or more frequently, as this method fills the galleries with suffocating vapours and smoke, to be broken in pieces with bruising-machines shod with pieces of iron weighing 150 lb.: which done, the fragments are carried out on the workmen's shoulders, night and day, each man passing them on to his neighbour in the dark, it being only those at the pit's mouth that ever see the light. . . . When these operations are all completed, beginning at the last, they cut away the wooden pillars at the point where they support the roof: the coming downfall gives warning, which is instantly perceived by the sentinel, and by him only, who is set to watch upon a peak of the same mountain. By voice as well as by signals, he orders the workmen to be immediately summoned from their labours, and at the same moment takes to flight himself. The mountain, rent to pieces, is cleft asunder, hurling its débris to a distance with a crash, which it is impossible for the human imagination to conceive; and from the midst of a cloud of dust, of a density quite incredible, the victorious miners gaze upon this downfall of Nature. Nor yet even then are they sure of gold, nor indeed were they by any means certain that there was any to be found when they first began to excavate, it being quite sufficient, as an inducement to undergo such perils and to incur such vast expense, to entertain the hope that they shall obtain what they so eagerly desire.

"Another labour too, quite equal to this, and one which entails even greater expense, is that of bringing rivers from the more elevated mountain heights, a distance in many instances of 100 miles perhaps, for the purpose of washing these débris. . . . Then, too, vallies and crevasses have to be united by the aid of aqueducts, and in another place impassable rocks have to be hewn away, and forced to make room for hollowed troughs of wood; the persons hewing them hanging suspended all the time with ropes." When the water reaches the level ground, trenches have to be dug for its passage, which are lined with planks and covered at the bottom, at regular intervals, with a layer of *ulex*, "a plant like rosemary in appearance, rough and prickly, and well adapted for arresting any pieces of gold that may be carried along. . . . The earth, carried onwards in the stream, arrives at the sea at last, and thus is the shattered mountain washed away, causes which have greatly tended to extend the shores of Spain by these encroachments upon the deep." Whether shafts or galleries are used, the gold obtained is pure gold, and is often found "in lumps, sometimes exceeding 10 lb. even. The names given to these lumps are *palagæ* and *palacurnæ*, while the gold found in small grains is known as *baluce*. The *ulex* that is used for the above purpose is dried and burnt, after which the ashes of it are washed upon a bed of grassy turf, in order that the gold may be deposited thereupon. Asturia, Gallæcia, and Lusitania furnish in this manner, yearly, according to some authorities, 20,000 lb. weight of gold, the produce of Asturia forming the major part. Indeed, there is no part of the world that for centuries has maintained such a continuous fertility in gold. I have already mentioned that by an ancient decree of the senate, the soil of Italy has been protected from these researches; otherwise, there would be no land more fertile in metals. There is extant also a censorial law relative to the gold-mines of Victumulæ, in the territory of Vercellæ, by which the farmers of the revenue were forbidden to employ more than 5000 men at the works."

Livy mentions that the gold of the splendid ornaments of fine gold worn by the Roman matrons, came from the district of Tamaya, in Spain. Recent attempts have been made to discover the mine whence it came, and an old shaft was found, which, when cleaned out, laid open extensive Roman galleries. A lode of ferruginous conglomerate, 32 in. wide, was discovered, containing visible gold, and samples are said to have given by assay, 22 to 24 oz. of gold per metric quintal (less than 2 cwt.).

Cardonne informs us that "The mines of gold and silver which existed in Spain were a great source of wealth to the Arabs; they employed a large number of workmen, and extracted a great quantity of those metals." The chief mines of the Arabs appear to have been in the province of Jaen, where, even now, on the hills, more than 500 shafts may be seen.

Piquet says that in the sixteenth and seventeenth centuries, the province of Santander was known to contain mines of gold, the localities of which are mentioned in the archives of Simancas.

According to Laur's report, Post-Tertiary extinct river-beds, like the dead-river deep leads of California, cover many sq. leagues in Spain, in some places capped by volcanic rocks. Samples were taken from 2 districts :—Cénès, in the hill which separates the Rio Daro from the Rio Genil; and Huetor, on the plateau between the valley of the Genil and that of Monachil (in and around the town of Granada). The deposit extends far to the N. of the Nevada of Granada, as well as E., W., and S.W., lying on the lower part of the slopes of the hills, and underlying the more recent deposits of the plain of the Vega.

Roswag states the yearly gold-production of Spain at a maximum of 700 lb.

SWEDEN AND NORWAY. *Lapland.*—The history of the Lapland gold-discoveries is as follows. In 1867, the Swedish engineer Dahl, while exploring the district of Lappmarken, on the borders of Russia, came upon auriferous alluvions in the river Tana. Crossing into Russian territory, he discovered gold along the right affluents of this river, and on the Ivalo, discharging into Lake Ehnarch, and ultimately falling into the Arctic Sea. Two Californian miners extracted 60 oz. of gold here as the result of a summer's work in 1869. The official statistics of the yield of the 8 years' washing in Finnish Lappmarken are :—

	oz.		oz.
1870 ..	615	1874 ..	725
1871 ..	1822	1875 ..	546
1872 ..	1770	1876 ..	318
1873 ..	1030	1877 ..	224

This gives a total of 7050 oz. The relative proportions from different streams were :—6388 oz. from the Ivalajoki, 566 oz. from the Palsioja, 86 oz. from other little streams falling into the Ivalajoki, and 10 oz. from the Luttajoki. The largest nugget yet found weighed about 65 gr.

SWITZERLAND.—Switzerland possesses no gold-mines nor -washings at the present moment, though it would appear that much of the alluvial gold worked in the streams just over the border in France (p. 709) and Italy (p. 715) is really derived from a Swiss source. Formerly small quantities were found at the foot of Mount Calanda, close to Feldsberg, near Chur, enclosed in schistose quartz and calcspar. Remunerative washings used also to be carried on in both the rivers Emmen, and in the Reuss, as well as in the Rhine, near Bâle.

TURKEY IN EUROPE.—According to Strabo (fragment 33, 34: Bohn's library, i. 512), "There are about the Strymonic Gulf other cities also, as . . . and Datum, which has an excellent and most productive soil, dockyards for ship-building, and gold-mines. There are numerous gold-mines among the Crenides, where the city of Philip now stands, near Mount Pangæus. Pangæus itself, and the country on the E. of the Strymon, and on the W. as far as Pœonia, contains gold- and silver-mines. Particles of gold, it is said, are found in Pœonia in ploughing the land."

The Abbé Bartholemy places the date of Cadmus' first working of the gold-mines in Pangæus at 1549 B.C. Philip of Macedon worked them in 358 B.C., and derived most of his treasure from them. The yield of Thracian gold in his day has been estimated at 1000 *talents* a year, equal to 340,000*l.* or to 5,000,000*l.*, according to the value given to the *talent.*

Herodotus says (bk. vi. c. 46–7: Rawlinson, iii. 436–7), "They were masters of the gold-mines of Scapté-Hylé, the yearly produce of which amounted in all to 80 *talents.*" Scapté-Hylé is said by Stephen to have been a town upon the Thracian coast, opposite Thasos. It was probably near Datum, to which its gold-mines seem sometimes to be ascribed. The wife of Thucydides was, we are told, a native of this place, and the owner of some of its mines. Thasos is said to have been called Chrysa by the early Greeks, on account of its gold-mines. Also, "These Phœnician workings are in Thasos itself, between Coenyra and a place called Ænyra, over against Samothrace: a huge mountain has been turned upside down in the search for ores." That is on the S.E. side of the island. Coenyra still remains in the modern Kinyra. The site of Ænyra cannot be fixed.

Again (bk. vii. c. 112: Rawlinson, iv. 93), "with the long high range of Pangæum upon his right, a tract in which there are mines both of gold and silver." The whole region from Philippi and Datum on the E. to Dysorum on the W. was most rich in the precious metals. Aristotle relates that after heavy rains "nuggets" of virgin gold were often found of above 1 lb. weight. There were two—one of 3 and one of 5 lb.—in the possession of the Macedonian kings. And (bk. ix. c. 75: Rawlinson, iv. 433), "in a battle with the Edonians near Datum, about the gold-mines there, he [Sophanes] was slain." Datum or Datus was a Thasian colony on the coast of Thrace, lying between Abdêra and Neapolis. The battle here mentioned was fought about the year B.C. 465, on occasion of the first attempt which the Athenians made to colonize Amphipolis.

Pisistratus, when he obtained possession of Athens, was in receipt of funds from the country itself and "from the Strymon river" (Clio, i. 64: Laurent, i. 31). The country between the Strymon and Nestus abounded in mines of gold and silver. Nestus is in long. 24° 40′, lat. 41°. A river of Thrace, it comes from the E. extremity of Mount Scomius, flows between Mounts Rhodope and Pangæus and falls into the Ægean at 60 miles from the mouth of the Strymon, called by the Turks Cara Souï. Strymon, long. 23° 50′, lat. 40° 50′, a river of Thrace, rises in Mount Scomius, and falls into a bay of the Ægean Sea, of which the modern name is Contesa or Orphani.

A German mining engineer named Fischbach, in the Turkish service, gave Davis (1879) an interesting account of his discovery of the ancient gold-mines, worked by Philip of Macedon and Alexander the Great, some 7 to 8 hours from Salonica, on the river Kilik. There was a great number of chambers connected by galleries, many of which were so low and narrow that they could only be explored by crawling. He had observed in one place a rich vein of silver, which the old miners had neglected: they must therefore have found something more precious; but he could discover nothing except oxide of iron, mixed with an earth; he had tried some of this with mercury, and obtained a small quantity of gold, enough to "pay"; but the Turkish Government refused to give a concession for working the mine. Fischbach thought the old miners worked in a rough and wasteful way, by washing the mineral, and gathering the gold as it was precipitated down the course of the stream, so that much must have been lost.

As the part of the mainland opposite Thasos was famed in ancient times for gold-mines, Tozer (1869) inquired whether any minerals were discovered at the present day; all, however, that he could learn was that quartz is found all about Cavalla, and that therefore it is likely enough that there is gold, but that no traces of mines had been discovered.

On the slopes of Olympus, in the vale of Tempe, an English company has for many years been engaged in mining operations, chiefly among the silver- and gold-deposits. A celebrated Russian writer says the Pactolus would pay to work now, if not as great as it did to Crœsus, yet in quantities that would astonish the world.

Woodward (1873) says that no ores of any kind are known at Despoto-Dagh, save small quantities of gold which are washed out of the alluvium near Balukkiöi. He adds that gold in small quantities is obtained by washing near Slatica.

UNITED KINGDOM.—Gold and silver are enumerated by Strabo (iv. 279) among the products of Great Britain. The Romans were acquainted with this, and our precious metals proved one incentive to their ambition in effecting our conquest. Thus Agricola, in his oration to his soldiers before the battle of the Grampian Hills, excites them to victory by reminding them "Fert Britannia aurum et argentum, et alia metalla pretium victoriæ." On their first landing in Britain, the Romans found the inhabitants in possession of gold and gold coin. But Murchison has expressed a belief that "in our own country, as in many others, the quantity of gold originally imparted to the rocks was small, and has to a great extent been exhausted." Modern official statistics of the total gold-production of these islands are :—

Year.	Oz.	£	Year.	Oz.	£
1861	2784	10,816	1869	18	62
1862	5299	20,390	1870	191	750
1863	552	1,747	1871	..	..
1864	2887	9,991	1872	..	..
1865	1664	5,824	1873	..	..
1866	743	2,656	1874	385	1540
1867	1520	5,890	1875	579	2105
1868	1012	3,522			

England. Cornwall.—Pennant (1810) observes that gold is to this day found in Cornwall, mixed with tin and other substances. The largest piece then discovered was equal in weight to 3 guineas. He thinks it probable that it was Cornish gold which proved the lure to the Romans, for it was impossible that they or the Phœnicians could have been ignorant of it.

Sir Christopher Hawkins, Bart. (1818), describes a piece of gold found in streaming for tin, in a moor near the church of the parish of Ladock. The specimen of gold intermixed with quartz appears to have formed a part of, and to have been broken off from, a lode ; pieces of quartz intermixed with gold have not been frequently found. In streaming the moor from S. to N., the gold, probably washed down by the river, was not found to the N. of a certain line ; the lode therefore must cross the valley near this line, above which no gold was found in an E. and W. direction.

Pattison (1854) remarks of the parish of Davidstowe, in the north of Cornwall, situated at the edge of the granitic boss of Roughtor, that the Devonian rocks are here traversed by siliceous bands in the form of veins of coarse quartz. These are subordinate quartzose portions of the slate rocks, not cross-courses or strings, but metamorphic conditions accompanying fissures in the line of the bedding and strike, and attended with the segregation or addition of various minerals. They were produced by a cause affecting apparently the whole mass. The veins are variable in character as regards the admixtures present with the quartz. Trappean matter is often visible, usually mica, rarely pyrites. In some places, the quartz is much intersected by ferruginous partings and hollows ; these contain "gossan," varying in colour from light pink to dark red-brown. It is these gossaniferous portions in the vicinity of trappean matter which have been found to be auriferous. In the summer of 1852, from a portion of a quartz vein at Davidstowe, he obtained a trace of gold. Other samples have given 11 oz. 13 dwt. 8 gr. of gold per ton.

Devonshire.—In Devonshire also, the red and brown gossans contain a percentage which some think will pay the cost of extraction. The Britannia gossan from Devonshire yielded by experiments in 1853, 13 dwt. and 1 oz. 0 dwt. 20 gr. per ton. The Poltimore gossan has given 17 to 32 dwt. per ton, and other Devonshire ores 9 oz. to the ton.

Lancashire.—The geological features of the Australian gold-fields have been declared similar to the quartz veins in the Silurian rocks of Seathwaite, near Broughton-in-Furness, in this county, which are auriferous, and which have several times been proposed to be wrought for gold. In Australia, as well as in Lancashire, the quartz veins are in Silurian deposits in the vicinity of granite; in the latter county, near the granitic district of Ravenglass. The size of the quartz veins here has prevented their being wrought with success.

Somerset.—Stoddart has described (1876) the unusual occurrence of the presence of gold and silver in a sample of Carboniferous limestone taken from a quarry in the neighbourhood of Clevedon. He remarked the absence of sulphur and silica, which so often accompany gold-deposits. Analysis gave:—silver, ·0023; gold, a trace. The amount of silver varies from 94 gr. per ton to nearly 1 oz.; the gold from 3 to 5 gr. per ton.

Worcester.—At Bromsgrove Lickey, near Birmingham, has been found (1864) siliceous rock impregnated with the precious metals, and it would appear from some accounts that the only difficulty is the treatment which the rock should be subjected to, to obtain profitable results, as samples of ore taken out of a stone-pit by the roadside going up the hill were found to contain both gold and silver.

Ireland.—Towards the close of 1796, gold was accidentally discovered in the Ballinvalley—since called the Gold Mine—brook, a tributary of the river Aughrim, which rises on the E. slope of Croghan Kinshela, and falls into the Avoca at the Wooden-bridge. Several hundred people dug and searched for gold in the banks and bed of the stream, thus collecting a considerable quantity, for nearly 6 weeks; the Government then took possession, and carried on the working with some little advantage until 1798, when their works were destroyed by the rebels. In 1801, proceedings were resumed at Ballinvalley, and examinations were commenced at Croghan Moira, Ballycreen, and Ballynacapogue. At Croghan Moira, gold was obtained, though in very small quantity; at Ballycreen, minute particles of gold were found; in Ballynacapogue brook, small particles of gold were obtained, but as the re-opened stream-works became less productive, and as the other localities had afforded very little gold, operations were discontinued in 1802. Since then, the neighbouring cottagers have obtained a little gold from the refuse of the Government works and the beds of the streams, but scarcely sufficient to afford them the means of subsistence. In several other parts of the district, S. of the sulphur-course, particles of gold have been found; but they have not tempted the discoverers to extend their operations. The detrital matter is, for the most part, shallow enough to be conveniently wrought by open-cutting; although in one instance at least, its depth is so great that it has been worked, in shafts sunk to the rock ("shelf") and by drifts (levels) extending along its surface, more cheaply than by the removal of the whole overburthen.

The deposit consists, in great measure, of gravel, shingle, boulders, and angular blocks of various slates, mixed, here and there, with pebbles of granite, and smaller quantities of many other earthy substances, as well as with masses of several ferruginous minerals, some amount of tinstone, small fragments of sundry other ores, and gold in minute proportions; all imbedded in sand and clay, the débris of neighbouring rocks. Some of the earlier nuggets weighed several oz. apiece; but, even then, most of the gold consisted, and now the whole consists, of scales and granules of merely a few gr. each. In many of the specimens, however, metallic threads interlace a matrix of wolfram, or of brown iron-ore. Whether the masses are, large or small, of auriferous matrix or of pure metal, mostly they seem to have suffered great attrition; yet amongst them, small well-preserved crystals of gold have been sometimes obtained. The gold procured by Government ranged from 21⅜ to 21⅞ carats fine. It is believed that the peasantry collected during the 6 weeks in 1796, about 800 oz. of gold; the Government, from 1796 to 1802, obtained 944 oz. 4 dwt. 15 gr., value 3675*l.* 7*s.* 11½*d.*; from 1857 to 1862, the Carysfort Mining Co. extracted about 85 oz. It is impossible to ascertain the amount secured by the cottagers since 1802.

At Ballymurtagh, gold is associated with the earthy brown iron-ore which abounds in the upper portions of both the sulphur-courses; but the only reliable analysis shows that it averages less than ⅓ oz. (0·000010 per cent.) to the ton of veinstone. The more deeply-seated pyritous parts of both formations are also auriferous, but in a still smaller degree. In 1854, a considerable quantity of gossan, carefully selected from shallow parts of the Great North sulphur-course in Ballymurtagh, was submitted to operation in 2 machines then newly invented for washing gold. The results reported to have been obtained were—in the first machine, at the rate of 17 dwt. 12 gr. (0·000027 per cent.) of gold per ton of ore; in the second machine, 7 dwt. 12 gr. (0·000011 per cent.) of gold per ton; another experiment in the second machine gave more than 1 oz. per ton. The Directors of the Wicklow Copper Mines Co., having little confidence in such conflicting results from the very same ore, placed other samples of it in the hands of Prof. Apjohn, whose analysis showed much smaller proportions of gold than the lowest of those reported by the machinists. Gold is sprinkled through the iron-pyrites in both the sulphur-courses; but the proportion is even smaller than in the gossan.

Gilbert Sanders has remarked in the gold-valleys of Wicklow a close geological similarity to those of New Zealand. The drift-gold, however, of which there is plenty, had not yet been clearly traced to any one of the quartz veins in Croghan Kinshela mountain, neither by the Carysfort Mining Co., nor when Government formerly worked the district. Magnetic iron appears also in Wicklow, as at Auckland and elsewhere, with the gold-rocks. Dr. Haughton states that Croghan Kinshela, on the flanks of which are the gold-streams, is a granite mountain of an extraordinary diversity of composition.

Scotland.—The most complete and scientific account of the gold-fields of Scotland is given by Dr. Lauder Lindsay, who, while visiting, in 1861, the auriferous districts of the province of Otago, New Zealand, was much struck with the similarity, as respects physical geography and geology, between that country and many parts of Scotland. It occurred to him that, in so far as the physical conformation obtained, and the same geological structure existed in many parts of Scotland, there should be a co-equal diffusion of gold as respects at least its area, and he proposed to himself to determine how far this suggestion or belief would be borne out by actual investigation. Since that period, he has given all the attention that opportunity permitted to the subject of the diffusion of gold in Scotland, both as regards its area and quantity. In 1863, he paid a special visit to the Leadhills district, which, some centuries ago, yielded to systematic working upwards of half a million's worth of gold, and which, regarded by the test of its then productiveness, is fairly entitled to the appellation of a "gold-field." In order to compare the Scottish gold and gold-rocks with those of other auriferous countries, he made a special examination of the International Exhibition of 1862, and of all the museums accessible to him in Britain, Australia, and New Zealand. His general results or conclusions are:—

1. That gold is much more extensively or generally diffused in Scotland than has been supposed.

2. That the area of diffusion, and the extent to which it occurs, can only be determined by systematic investigation, equivalent at least to the "prospecting" of gold-diggers.

3. That hitherto, and with certain limited and local exceptions, there has been no such systematic prospecting in Scotland; and

4. That there are indications, if they do not always amount to proofs, of the existence in Scotland both of auriferous quartzites—that

is, of gold *in situ*—and of auriferous "drifts," using the term "drift" in its most comprehensive sense.

Before making general observations on the Scottish gold-fields, or comparing them, as regards their richness or extent, with those of other auriferous countries, which are better known, Dr. Lindsay gives briefly the principal results of his observations and inquiries at and concerning what he denominates the Crawford or Leadhills "gold-fields"; the whole of that moorland and hill region of the southern highlands—Upper Clydesdale—the southern extremity of Lanarkshire, variously known as Crawford, Crawford Moor, or Crawford-Lindsay, which includes the district now known as the Leadhills, and forms the watershed of the 4 great southern rivers (the Clyde, Nith, Tweed, and Annan), has repeatedly, and in various ways, proved to be more or less auriferous. Calvert prospected the whole Leadhills district, and found gold in every gully and valley.

Griffin also prospected the whole district with the similar result, that he found gold in dust or grains "everywhere." But long prior to their modern system of prospecting, some of the Leadhills valleys were the scene of the far-famed alluvial washings under Sir Bevis Bulmer in 1578–92, and it was from the produce of such washings that the Scottish Regalia were fashioned in 1542, and Kings James IV. and V.'s celebrated bonnet-pieces coined. Bulmer's chief washings are said to have been in the valley of the Elvan, and he is also represented as having washed the whole bed of the Glengonner water. But vestiges of ancient "diggins," precisely similar to those of Otago, are to be met with in many parts of the Leadhills district. For instance, Lindsay found the haugh or "flat" on the banks of the Glengonner water above Abington and immediately below Glencaple Burn, covered with a series of quartz-like mounds, exactly resembling those with which he was familiar in the famous Gabriel's Gully at Tuapeka in Otago, and which are said really to mark the site, or one of the sites, of Bulmer's celebrated workings. It was the gold-prospecting in this district, it is said, that led to the discovery of the lead, which has proved so much more permanent a source of prosperity to the district, to which it has, moreover, given its distinctive modern name of late years; and at present gold is systematically collected by the Leadhills miners chiefly in certain localities, viz. in the Windgate or Windygate Burn, in Langcleuch Burn, in Bellgall Burn, in the whole course of the Elvan and Glengonner from the Clyde to their source.

The gold occurs chiefly in the gravelly clay, locally known as "till," as this coats the flanks of all the Leadhills valleys; but it is also to be found in the shingle, gravels, or clays of the stream-beds. Several of the miners have considerable reputation as skilful and successful gold-finders, and their practised eyes are constantly finding gold in both localities, the hill-sides and the stream-beds. This gold is invariably known as "drift" or "alluvial" gold. There is no present local evidence of the existence of auriferous quartzites. But in 1803, the late Prof. Traill of Edinburgh found gold in a vein of quartz *in situ* at Wanlockhead. All the gold belonging to this district which Lindsay has seen is of a granular or nuggety character, and quite comparable with the usual produce of Otago, or other auriferous countries. Some of the nuggets found in former times, and preserved in the cabinets of local proprietors, are of considerable size and value. The cabinet of the late Lord Hopetoun contains two—one of them weighing 2 lb. 3 oz. = 27 oz., or 12,960 gr., which at the current price of gold in Australia, 4*l.* per oz., is worth 108*l.*, collected, it is said, about 1502, prior to the systematic workings of Bulmer; the other, weighing 1 oz. 10 dwt., or 720 gr. The first would appear to be by far the largest mass of native gold ever found in Scotland. Since, however, systematic gold workings on a large scale were discontinued, the size of the Leadhills nuggets has been much smaller, the largest seldom now exceeding 2 or 3 gr., though they are frequently found of that size. Just previous to Lindsay's visit in the autumn of 1863, a nugget of 30 gr. had been found, and another single nugget, whose weight he failed to ascertain, sold for 25*s.* at Abington. More generally the gold occurs here as rough granules, coarser and larger than those constituting what could properly be called "dust," and of this considerable quantities are frequently collected in limited periods for special purposes, such as marriage gifts or jewellery, to or for the local proprietors. Thus, in a fortnight in 1862, 975 gr. were collected for the Countess of Hopetoun, and on another occasion 600 gr. in 6 weeks by 30 men at spare hours, 15 working in the forenoon, and the other half in the afternoon. About Abington, in 1858, similar quantities were collected under similar circumstances, to furnish marriage jewellery for Lady Colebrooke. Between May and October 1863, three miners in the intervals of leisure from their usual work, collected for Dr. Lindsay 33 gr., which they found in the "till," about 40 yd. above the bed of the stream, half-way down the Langcleuch Burn, between Leadhills and Elvanfoot: their charge was 20*s.*, that is, at the rate of about 15*l.* per oz., or 7½*d.* per gr. During the last 5 years, the price of crude gold in Australia and New Zealand has averaged 3*l.* 17*s.* 6*d.* to 4*l.* per oz., so that the Scottish diggers obtained for their produce nearly 4 times as much as the New Zealand or Australian diggers got for theirs. The price appears at first sight to be extremely and disproportionally high; but the cases are by no means parallel; for in the case of the Leadhills gold, the collection is made to meet demands for cabinet specimens, or for jewellery materials, under circumstances quite exceptional. The Leadhills miners collect their gold mostly to order; it is thus at once disposed of, and hence gold is seldom to be found there for sale, or only in very small quantities. On one occasion Lindsay was offered a sample of 140 to 160 gr. for 5*l.*, that is, at the rate at which he purchased his smaller sample, but the miners rarely have so much in their possession unsold. In the summer of 1862, by way of holiday work, the miners frequently collected quantities of 15 to 54 gr. The able-bodied Leadhills miner never, however, gives up his usual labour, at which he earns 15*s.* per week, for the more precarious gains to be derived from gold-finding. To gold-seeking he devotes only his spare hours, his holiday time, or his periods of sickness or debility. The director of the mines at Leadhills has such an opinion of the abundance of the gold, the facility with which it may be collected, and the probable remunerativeness of the gold-working, that with a favourable lease of the ground, he and many others would at once combine to commence systematic operations. Other local authorities are, however, much less sanguine of profitable results from working the gold on a larger scale, or by whatever means, though there is unanimity of opinion as to the general prevalence of gold, and its easy accessibility, throughout the district.

The method of collecting gold by washing at Leadhills is essentially that employed in the early history of gold-diggings in all auriferous countries; but there can be no doubt that collection would be facilitated, the produce increased, and the remunerativeness of the operation improved by the application of the most modern machinery now used in countries where gold-mining has long been a settled industry.

The Scottish gold-fields may be divided geographically or topographically into three—the Northern, Central, and Southern.

1. The Northern comprises the greater part of the counties of Sutherland, Ross, Inverness, and Argyle, north of the Caledonian Canal. It occupies the longitudinal axis of the northern peninsula of Scotland, is second in size only to the central area, and has yet almost entirely to be explored.

2. The Central lies between the Caledonian Canal and the valley of the Tay; includes a great part of the shires of Inverness (southern half), Aberdeen, Banff, Kincardine, Perth, Forfar, Argyle, Stirling, and Dumbarton. It is far the largest of the 3 areas. Like the Southern gold-field, it forms a transverse belt across Scotland, and much of it remains to be explored.

The Southern comprises great part of Dumfries, Kircudbright, Wigtown, Ayr, Selkirk, Peebles, and Lanarkshire, and includes more particularly parts of the districts of Nithsdale, Annandale, Eskdale, Ettrickdale, Tweeddale, and Clydesdale, and the Lammermuirs (in Haddington and Berwick). It is the smallest of the 3 areas, but it is the best known, and, so far as ascertained, the richest.

Geologically, the area of these 3 great gold-fields is that occupied in Scotland by the Lower Silurian strata and their drifts. These strata are divisible, however, only into 2 great groups, viz. the Southern, corresponding to the Southern gold-field as above delineated, characterized by the greywackes of the Southern; and the Northern, comprising that above described as the Northern and Central gold-fields, characterized by the micaceous schists of the Grampians.

At many localities throughout the area which Dr. Lindsay assigns to the Scottish gold-fields, actual finds of gold have been made in recent or former times, and this is one of the strongest arguments for their thorough exploration. Of such gold-finds, the following will suffice as illustrations :—

I. Northern Gold-field.

1. Sutherlandshire.—Helmsdale water. A nugget found here in former times weighed 10 dwt., or 240 gr.

II. Central Gold-field.

1. Perthshire.—(A.) Breadalbane, area of Loch Tay, and head-waters of the Tay. A nugget found in former times weighed 2 oz., or 960 gr. Sir James Simpson was shown a specimen of gold, with its matrix (quartz), by the late Marquis of Breadalbane, from Lyndrum. In 1861, Prof. Tennent of London found gold in quartz, associated with iron-pyrites, at Taymouth.

(B.) Upper Strathearn, area of Loch Earn, and the head-waters of the Earn. Glen Lednoch (Ritchie); streams falling from the north into Loch Earn (Ritchie); Ardvoirlich, south side of Loch Earn.

(C.) Glenalmond (Mercer); Glenquoich and other valleys of the Grampians.

2. Forfarshire.—Clova district, areas of Angus, Edzell, and Glenesk.

3. Aberdeenshire, area of the Dee, Braemar, Invercauld, coast about Aberdeen, and in the sea-sand.

In New Zealand, and other auriferous countries, gold is very commonly associated with magnetic-iron sand, containing or not, titanium and other minerals, or with iron sulphides. It is of interest to know that the sands of the Dee, which consist mainly of the débris of granite and gneiss, contain considerable quantities of magnetic-iron sand and iserine, with which are associated smaller amounts of titanium, uranium, and arsenic. The gneiss of Braemar often contains much magnetite in place of mica (Nicol), while iron or oxides or sulphides are common in all the schists and granite of Aberdeenshire (Nicol).

4. Argyleshire.—Dunoon.

III. Southern Gold-field.

1. Head-waters of the Clyde, including the Ech, Crawford Moor or Leadhills district; Elvan water, Glengonner, Glencaple, Winloch, Short Cleuch, Lamington Burn.

2. Head-waters of the Tweed; Manor water, which flows north to the Tweed; Meggat water, which flows south to St. Mary's Loch; other feeders of the Yarrow and Glengaber.

There are traces of prospecting and digging in former days in Meggat water valley, similar to those which occur in Leadhills. In the British Museum, Lindsay saw two specimens of Tweeddale gold, the one nuggety, and in quartz, a very rich sample, the other granular rather than nuggety. Griffin prospected St. Mary's Loch district, and found gold in dust or granules everywhere.

3. Head-waters of the Annan, Moffatdale; streams falling into Moffat water; Hartfell range, about Dobbs Linn, several small finds of gold were made in the summer of 1863, and one small nugget, weighing about 6 gr., was exhibited in Moffat (*Scotsman*, Aug. 10, 1863).

Speaking in greater detail of the Fifeshire gold-diggings of 1852, Dr. Lauder Lindsay says the Lomond gold-digging mania occurred in May 1852, and lasted about a month. There was a daily average of 300 diggers—at least 5000 to 6000 in all. Many of them were coal and iron miners, who were earning 15*s.* per week or upwards, and who had thrown up their employment to embark in the alluring lottery of gold-seeking. The excitement extended over an area of 20 miles, including the opposite shores of the Forth and Tay. The origin of the mania was the statement of a convict, a native of Kinnesswood, who wrote from Australia to the friends he had in the Kinross-shire village, that he had often seen gold at home in the lime-quarries above Kinnesswood, in the Bishop's Hill, similar to what was being dug in Australia. At this particular time, the public mind was in a condition of great excitement, produced by the brilliant auriferous discoveries in California in 1847, intensified and revivified by the no less splendid results of gold-digging in Australia in Sept. 1851; added to which, there were certain floating local popular traditions or proverbs which gave a spurious weight or significance to the convict's rash and inconsiderate assertion. The centre of attraction to the Fifeshire diggers—the chief scene of their labours—appears to have been a quarry of Carboniferous limestone, known in the district as the Clattering, or Clattering Well. This quarry is situated right above the village, and north-west of Kinnesswood in Kinross-shire, "about a gun-shot back from the brow of the Bishop's Hill," near its summit. Its locality is on the south base of the West Lomond Hill, overlooking Loch Leven. Superjacent to the limestone, which is richly fossiliferous, is a bed of ochre, abounding in globular masses of iron-pyrites, known to the quarrymen as "fairy balls," from the size of a fist to that of a man's head. Incredible as it may appear, these iron-pyrites were dug out and carried away in large quantities in the mistaken belief that they were lumps of gold.

Alluding to a sample of Sutherlandshire gold found at Kildonan, Dr. Lauder Lindsay compared it with (1) those of many hundred specimens of native gold which he had opportunity of examining from all the principal auriferous countries of the world, of whose characters he made memoranda at the time, and (2) with those of the gold specimens in his private cabinet, minerals from (*a*) New Zealand, (*b*) Nova Scotia, and (*c*) Scotland (Leadhills); and, as the result of the comparative examination, states his opinion that the Kildonan gold is of average quality, and that in particular, it so closely resembles gold he brought from the famous Gabriel's gully, in Otago, New Zealand, in 1862, that it is indistinguishable therefrom by the eye, even aided by the lens. It may be safely accepted as proved, he says, that the Sutherland gold now being obtained is of excellent quality. What has yet to be proved is the amount in which it occurs; and this can be done only by experienced gold-miners—by shaft-sinking and quartz-crushing—by co-operation of labour and investment of capital. The Kildonan gold he has seen is mostly in the form of flattened nuggets, of small size, smaller than those in his cabinet from Leadhills. The size of individual nuggets is of little consequence, compared with the total amount distributed in drifts or quartzites; for in the latter, gold may be present in amount that will pay extraction when it is, nevertheless, invisible to the naked eye.

A specimen of gold, consisting of "dust" and "grains," from the Kildonan Burn, Sutherland, examined by David Forbes, gave the following results of two separate analyses:—

Gold	81·11	81·27
Silver	18·45	18·47
Silica (quartz)	0·44	0·26
	100·00	100·00

The largest particle weighed 4·6 troy gr. A specimen of alluvial gold, in "grains," procured by Alexr. Grigor, from the estuarine mud of the river Molyneux, Otago, New Zealand, bore a very great resemblance to the Kildonan gold. P. G. Wilson says (Feb. 1869), that the gold which has yet been found is in small grains. A few nuggets have occurred weighing 1, 2, and 3 dwt., and one has been got of 5 dwt.; but the largest quantity is in dust, with pretty much magnetic-iron dust.

According to Thost (1860), at Loch Earn Head, several galena-veins, of inferior importance, have been discovered in a stratum of calcareous schist. Their outcrop is overlain by gossan, in which particles of native gold appear to have been found. Certain it is that arsenical pyrites, which was at one time met with as an accessory mineral, contained 6 oz. of gold per ton.

William Cameron (1870), pointing out the chief geological features of the Sutherlandshire gold-fields, says that, with the exception of certain strips and peaks of Old Red Sandstone, large-grained granite, and Oolite, the whole of the country immediately surrounding the diggings consists of metamorphic Lower Silurian rocks. No discovery of gold *in situ* has yet been achieved, so that the question as to what is the true matrix of the Sutherland gold is somewhat perplexing, and is exciting amongst geologists a considerable degree of interest. The drifts in which it is found are various, fine-grained gold and even small nuggets having been obtained in various strata, from the bed-rock to the roots of the heather. It exists in bands of black ferruginous drift, almost of the nature of cement, containing washed boulders of gneiss, granite, and schists. There are occasionally two distinct bands of this drift, with intervening beds of sand, drift, or felspathic clay, the lower one, which is always on the bed-rock, containing very large unwieldy boulders.

Gold was found in some half-dozen of the tributaries flowing into the Ullie from the north. Mining operations, however, had been confined chiefly to the Kildonan, the Suisgill, and the Torrish,—the two former being the more favourite grounds. Respecting the origin of the gold, Sir Roderick Murchison takes us to the grand central plateau of Sutherland, whilst Campbell of Islay, who has written a pamphlet on the subject, hesitates whether to travel a little farther, and carry us to Lapland and the Polar regions. Sir Roderick attributes the gold to the abrasion of the granites and metamorphic Lower Silurian rocks, in the interior, which have been carried by glacial action down the E. slopes of Sutherland and deposited in straths and valleys, such as those of the Ullie and its burns, the Kildonan, Suisgill, Torrish, &c.; whilst Campbell points to the fact of gold being found in Unst in Shetland, and in river-drifts in Scandinavia and Lapland,—and, referring to data collected by himself and others respecting the curves of the glacial flow, suggests the possibility of the gold being brought by icebergs and glaciers from these Boreal regions. The Rev. Mr. Joass is inclined to infer that the granite may yet be found to be the matrix of the gold, and remarks that the material in which granular gold occurs, namely, the detritus, is not necessarily far travelled, for it includes boulders of apparently local origin.

Cameron, whilst admitting all conclusions as yet to be more or less conjectural, is inclined to agree with Joass in ascribing the gold to a local origin, and probably to a granite matrix. With respect to the question as to whether the Sutherland gold-fields would pay to work, Cameron says, upon the whole, whilst doubting the desirability of these fields for individual labour, he was disposed to believe that with united enterprise and combined labour and capital, and with systematic and economical working, which would be vastly aided by the great natural advantages of the country, satisfactory results would be obtained.

Prof. Heddle (1880), in dealing with the geognosy and mineralogy of Scotland, having himself no means of sifting from the many reports in newspapers the true from the false as regards the finding of gold in the streams of Caithness, applied to Dr. Joass, of Golspie, and found that his experience was confined to an unsuccessful search in the Duke of Portland's land, and in the neighbourhood of the Scarabins, while he indicates reasons for receiving with caution and doubt all reported finds. Prof. Heddle then wrote to Dr. Lauder Lindsay, who has long taken an enthusiastic interest in the matter, and from him received the following list of reputed finds according to the newspapers of 1869–70, especially the *Northern Ensign* (Wick), in March and April, 1869 :—

1. In the beds, over the banks of the Beriedele water, throughout its course, down to the sea-beach.
2. In the Ord Burn, "in fair paying quantities."
3. In the Ansdale Burn, in fair paying quantities.
4. On the Braemore estate (Sir Robert Anstruther's), through which the Beriedele flows.
5. On the Langwell estate, on the flanks of the Scarabin Hills, by Gilchrist, the originator of the Kildonan diggings of 1869.
6. In the Langwell water.
7. In the Dunbeath water, and
8. In the Burn of Haster.
9. In the Lathernwheel Burn.
10. Various localities, the parish of Lathern : "existence proven."
11. In the Thurso river, at various points, such as Weydale, Acharvadale, Halkirk, the Glut.
12. In streams rising on Braemore.
13. In Strathmore, on Sir J. G. T. Sinclair's property.

Special references to the Caithness gold-localities are to be found in the *Northern Ensign* of Feb. 4th, March 4th and 25th, and April 1st, 15th, and 22nd, all 1869.

In Nov. 1870, Sir J. G. T. Sinclair wrote to the *Northern Ensign*, about gold that had been found on his property at Strathmore. Several other newspaper correspondents describe the Caithness gold, comparing it with that of Kildonan ; but they do not give their names, so that the only "authentics" that can be cited in connection with Caithness gold are Gilchrist and Sinclair.

Dr. Lindsay thus reduces the "authentics" to two, and, as it is very improbable that Sir J. G. T. Sinclair personally found or even sought for gold, it is probable that the "find" was of the same character as the other "newspaper" ones. So that the flanks of the Scarabins would seem to stand as the only indubitable Caithness locality.

French (1880) says that the alluvium over an area of about 50 sq. miles around Leadhills, in Lanarkshire, is auriferous. In many places, the precious metal may be rendered visible after 15 or 20 minutes' washing with the primitive wooden trough employed by the local gold-seekers. Frequently nuggets have been found weighing from 1 to 4 or 5 dwt., and these are often either contained in pieces of loose quartz, or have quartz fragments attached to them; there are therefore good reasons to believe that the gold found in the stratum of red clay lying immediately above the rock has been derived from the numerous quartz-veins which traverse the district. It is a rather remarkable feature of the Leadhills district that the lead and gold-bearing ground is bounded on four sides by particular forms of silica. On the S. boundary, Lydian stone occurs in great abundance. On the N., at Abington, red jasper prevails; towards Crawfordjohn, on the W., agates and cornelians are found,—these are sometimes of great beauty; and on the E., near where a specimen of pasty silica was found, chalcedony is often met with.

Wales.—According to Ansted, there can be little doubt that gold has been obtained in former times by washing the sands of several of the rivers that come down from the slate rocks in part of Wales. The Romans got gold from quartz lumps in slaty rocks at South Gogofan, about 10 miles W. of Llandovery. They also appear to have ground down the iron-pyrites of the same district, which they afterwards washed for gold. But it was not until 1843 that the Cwmheisian mines near Dolgelly, in Merionethshire, were first noticed by Arthur Dean, as containing something like a complete system of auriferous veins. An account of this discovery was communicated at the meeting of the British Association at York, in 1844. Since then, the mines have been partially worked. The Mowddach Valley and some of its small tributaries close to the town of Dolgelly, contain the chief mines that have been found to possess any quantity of gold. The metal occurs as usual in a native state, but is found in veins and flukany cross-courses, parallel and at right angles to the porphyry range, which here runs N. and S. through Merionethshire. The nearest fossiliferous rocks are the Lingula-beds of the Lower Silurian series, and the veins usually occur in underlying metamorphic schists. The matrix of the veins is quartzy, and the associated minerals are either galena and blende, or iron- and copper-pyrites. In addition to the gold in the vein-stone, minute particles are disseminated through the pyrites. Ansted noticed particularly that wherever any gold was present in veins, more or less magnesian mineral (generally chlorite or steatite) is found in the immediate vicinity. At the time of his visit, one of the strings of gold-bearing quartz in chloritic schist was opened, and he obtained from a few specimens of quartz, struck off whilst he was underground, very distinct threads and grains of gold, the general yield of the small quantity thus removed being at the rate of 60 oz. of gold to the ton of matrix. Further researches, however, failed to discover any quantity worth working. At Clogau, not very far off, other auriferous specimens, far richer, were obtained a year or two after his visit. Generally, it may be said that the gold-districts of Wales are limited to those places where the rocks are not only schistose but chloritic or steatic. They present a very marked resemblance to those of other countries where gold occurs more abundantly, but more especially to those of the S.E. states of N. America, where almost all the indications of the associated rocks and minerals are precisely similar. No doubt in former times, when nearly all the rivers of Western Europe brought down appreciable quantities of gold, or at least when the accumulations of ages were still untouched, the Welsh streams, as well as the German, French, and Spanish rivers, were rich in golden sands. These have long since been removed, and in Ansted's opinion, "at the present price of labour, and with the extreme irregularity of distribution that seems always to obtain where native metal exists, it is almost a hopeless chance to expect profit from mining or reducing establishments on a large scale."

The gold-bearing district of Merionethshire, lying between Dolgelly and the Moelwyn and Manod range, N. of Festiniog, was made the subject of a long report by Ramsay, in 1854, from which the following notes are taken.

N. and W. of the lower part of the river Mowddach, lie the lower portion of the Lingula-flags and the Cambrian rocks. The latter consist of the coarse, thick-bedded, greenish-grey grits of Barmouth and Harlech. These grits are overlaid by that part of the Lower Silurian rocks known as the Lingula-flags, which here consist mostly of blue slaty beds, generally more or less arenaceous, and partly interstratified with courses of sandstone. Both Cambrian and Silurian rocks have been penetrated by numerous greenstone-dykes. Many of them are of a light-grey colour and highly calcareous. Others assume the colour and texture of ordinary greenstone. Some of them are magnetic. Among the Cambrian sandstones, they run in all directions, sometimes with, but more generally across, the strike. In the Silurian region, they usually run more or less parallel with the lines of bedding. In the hard and solid Cambrian sandstones, the fractures into which they were injected were capricious and irregular; while in the Silurian shales, they have more frequently been intruded between the beds. Some of them fill cracks which pass into lines of lode.

The country in which the Dol-y-frwynog mine lies is interesting. A mass of very felspathic greenstone here breaks through a low part of the Lingula-beds. Three of the lodes yielding copper lie on its E. slopes; and a very little gold was detected in one of them, in the year 1836, by O'Neil. For 4 or 5 miles N. of this area, several other lodes occur in the Lingula-flags and their associated traps, on the banks of the Mowddach and the Afon-wen. The Cambrian grits, dipping E. at angles varying from 40° to 60°, are overlaid conformably by slaty beds of the Lingula-flags, traversed by greenstone dykes on the hills immediately N. of Pigswch. They are succeeded by a mass of intrusive greenstone, which is bounded on the N. by an E. and W. fault and lode on the N. part of Moel-Hafod-Owen. From this point, the greenstone passes S., with 2 interruptions, by Tyn-y-Ben-rhos to Moel Cynwch, about 2 miles farther S. E. of this greenstone are a set of rocks which possess a very peculiar lithological character, and which occur very sparingly elsewhere, either among the Lingula-flags or in any other geological area in Wales.

It is in a lode traversing this "country" that the most important of the gold discoveries has been made. The rock commences at what may be called the S.W. angle of Moel-Hafod-Owen, above Buarth. The same E. and W. fault that bounds the greenstone, limits it on the N. A line of fault drawn S. thence to where the brooks join, nearly opposite Dolan, forms its E. boundary so far. Thence, the Afon-wen forms its boundary for nearly 1½ mile S. It is not improbable that this may also be a continuation of the same line of fault. The boundary-line then crosses the stream, and still passes S. to the ground that lies between Cefn-mawr, and the precipitous rocks that overhang Mowddach above Dol-y-clochydd. The rock itself is one of those problematical masses to which it is difficult to give a definite name. In some places it is so hard and massive, that a hand-specimen is difficult to distinguish from some of the felspathic traps of the neighbouring country. Even then, however, it is more or less flaky, and constantly passes into a talcose rock, which in places at the surface and in the lodes decomposes into a kind of talcose unctuous clay. In many places, it graduates in the line of strike into ordinary slaty rocks, which then become largely interstratified with it. As it runs S. it becomes more and more slaty and sandy, and passes by degrees into rocks possessing all the characters of the Lingula-flags of the district. On the E., it is bounded by slaty Lingula-flags, on which rests the greenstone mass of Rhobell-Fawr. Several lodes occur in this country in the neighbourhood of Dol-y-frwynog and Cwm Eisen. The gold at Cwm Eisen was discovered in 1843, by Arthur Dean. It has been several times worked, but never with a steady profit. The gold is found in a branching lode containing lead. Its principal branch runs N.E., and is mostly composed of exceedingly hard quartz, which crosses the river about ½ mile above Rhaiadr Mowddach.

When Ramsay inspected the geology of this country in the spring of 1853, the most remarkable and promising lode was the new gold-lode at Dol-y-frwynog. It runs about W.N.W. and E.S.E. in the low ground S. of Moel-Hafod-Oven on the E. watershed. It is principally composed of a white saccharoid quartz, irregularly traversed by numerous small loose joints. Chlorite, decomposing talcose matter, and pink carbonate of lime are intermingled with it. In parts the quartz assumes a semi-granulated aspect, profusely intermingled with soft, unctuous, decomposing talc. It is largely charged with iron-pyrites. As a rule, the substance of the lode is easily shivered into fragments, a great advantage both in the original working of the lode and in subsequent operations. On examining a heap of quartz which lay at the mouth of the shaft, and turning over a few pieces, Ramsay readily saw with the naked eye, gold in small flakes and grains, irregularly disseminated through the quartz. In a more select heap of quartz, on all the pieces it was distinctly visible to the unassisted eye; and one mass in particular, heavier than a strong man could lift, was literally spangled all across its surfaces with rich glittering gold. Gold has also been detected by Byers in the matrix of the copper-bearing lodes about a mile farther S., and in the West Dol-y-frwynog lode these occur in the same talcose rock.

On the banks of Afon-wen, about a mile above the bridge, are some ruins of buildings, and below them, close to the river, the remains of charcoal-ashes and bits of bones, mostly covered with herbage. This place has a very singular, and, in conjunction with the gold discoveries, a very significant name, which it has maintained from time immemorial, expressive of gold having been melted or worked there. This name, Merddyn Coch 'r aur, signifies "the ruins of red gold." The tradition is, that the Romans formerly worked gold there.

Ramsay states on the authority of Byers, that in several spots in this neighbourhood where quartz-lodes occur, associated with copper, blende, lead, and talc, there gold has been found, instances of which he cites as occurring at Tyn-y-llwyn, near Moel Ispri, and other localities, principally in the Lingula-flags between Tyn-y-groes and the Mowddach, towards Barmouth, all in the area containing lead- and copper-lodes. It is also stated that gold has been detected in several other places N. of Cwm Eisen; as, for instance, at Penmaen, and at Gelli-gain, about 3 miles S.S.E. of Trawsfynydd; also in the Newborough mine, in an E. and W. lode immediately N.E. of Manod, and on the S. side of Moel-wyn, in blende and gossan. The whole of these lie either in the Lingula-flags or in the beds immediately adjoining above or below; and they lend some additional evidence to the views that have often been promulgated by Sir Roderick Murchison.

Whether all the reports in circulation of the occurrence of gold be actually true or not, it is at all events a fact that at Dol-y-frwynog it has been found in an unusual quantity, and also that its existence is certain in various other places. If in the lodes a considerable amount be scattered through the country, then Ramsay would expect that gold would be detected by washing the marine drift that rises on the mountains of North Wales to a height of over 2000 ft. In this drift it might in places be somewhat concentrated, partly by an ancient natural process of sea-shore washing, and partly by the more modern action of rivers, as in the case of the stream-tin of Cornwall, and of the gold in the superficial deposits of the Ural, of Australia, of California, and in those of Canada, some years ago discovered by Logan. Gold, in appreciable quantities, was, indeed, found by washing in the bed of the Mowddach, in the summer of 1852, by the Hon. Fred. Walpole and Sir Augustus Webster. Ramsay thinks it probable that in this river attempts might probably be most successful immediately below the confluence of the Mowddach with Afon-wen, and in places in the bed of the Wen, on the E. and S. watershed of the range of hills that runs from Tyn-y-Ben-rhos N. towards Moel-Hafod-Owen. In favourable spots, it might be well worth the pains to wash the detritus on the Mowddach between Dol-fawr and Gelli-gamlyn, and in the bed of the Wen from thence to Dol-y-frwynog. This opinion is founded on the fact that the talcose rocks which the Dol-y-frwynog lode traverses lie on the E. watershed of the above-mentioned range; and, if gold lie in them elsewhere in any parallel quantity between Moel-Hafod-Owen and the lower part of the Llanfachreth valley, then it might be expected in the detritus in the bed of the stream of the Dolan and the Gelli-gamlyn, nearly opposite to which, streams that traverse the talcose rocks empty themselves into the Mowddach.

Readwin observes that gold has been found in the mines known as Vigra, Clogau, Caegwian, Wellington, Victoria, Lachfraith, Cambrian, Prince of Wales, West Prince of Wales, Glasdin, Tyddyng-wladis, Dol-y-frwynog, North Dol-y-frwynog, Cwmheisian, Berthllwyd, and Caerwernog. He himself found gold in quartz, carbonate of lime, slate, chlorite-schist, blende, galena, copper-pyrites, iron-pyrites, tetradymite, and bismuthine; and of its occasional occurrence in extraordinary richness in the Clogau, Cambrian, and Dol-y-frwynog mines, he possesses remarkable proofs. To his own knowledge, so recently as 1856, as much as $14\frac{1}{2}$ oz. of gold were obtained from 100 lb. weight of quartz, taken from the Clogau mine, and many samples of 14 lb. weight from the Clogau and Cambrian mines have yielded in the proportion of 1 to 10 oz. to the ton of quartz.

Following is a statement of the return of gold from the Clogau mine :—

1861.	Ore crushed. tons	cwt.	Pure Gold. oz.
January	0	2	63
February	28	11½	171
March	40	18½	189¼
April	38	5	161¾
May	24	18	181¾
June	32	4	142½
July	28	2	257¾
August	13	6	144¾
September	61	2	304
October	54	18	358¾
November	58	5½	363
December	75	4	546
Total	455 tons.		2884

1862.	Ore crushed. tons	cwt.	Pure Gold. oz.
January	53	7	400
February	67	15	463
March	71	18	529½
April	62	13	566½
May	88	14	759
June	72	13	641
Total	417 tons.		3360

1863 .. 2886 oz., value 10,816*l.* 17*s.*

1878 .. 697 oz.

45 oz. 16 dwt. were said to have been got from a parcel weighing less than 1 ton.

Alluvial gold is found in the river Mowddach, near Dolgelly, from Rhaiadr Mowddach down to Cummer Abbey—a distance of fully 6 miles—gradually becoming less coarse as the river descends.

According to David Forbes, the Clogau lode occurs in the Lower Silurian Lingula-beds, close to their junction with the Cambrian strata of the Geological Survey; it runs about 18° N. of E. and dips at an angle of 88° to S., cutting through both fossiliferous strata and the intruded diabases, which are described as greenstones in the Survey; and it is, consequently, of later geological age than both these rocks, and is not improbably younger than the Silurian formation as a whole. The explorations appear to indicate that the lode is more auriferous at the parts where it cuts through the Lingula-beds, with their accompanying diabases, than at greater depth where it traverses the Cambrian grits. Among the accessory minerals found in the lode are tetradymite, iron-pyrites, chalco-pyrite, galena, chlorite, calcite, dolomite, chalybite, and heavy spar, which, as well as the gold, are distributed very irregularly in the quartz. When the quartz contains calcite, dolomite, and chalybite, or includes fragments of neighbouring clay-slate, it is regarded as likely to be more auriferous than when the lode consists of quartz only. When isolated fragments of the slate are found in the quartz of the lode, the gold and other metallic minerals are commonly found adhering to, or crystallizing on their under surfaces, which may have arrested these minerals in the act of being carried into lode-fissures from below with the stream of liquid quartz. The specific gravity of one specimen of gold was found to be 17·26, and 2 analyses showed the percentage composition of gold 90, silver 9·25, the remainder being quartz. Another alloy, lighter in colour and probably richer in silver, is sometimes met with in the lode.

A specimen of the dust washed from the bed of the Mowddach near Gwynfynydd, 8 miles from Dolgelly, contained small, flattened, elongated spangles of gold, the largest having the size of a pin's head, accompanied by abundance of fine, black sand, supposed to be magnetite, but found to be titanoferrite, together with some small particles of quartz, slate rock, mica, iron-pyrites, and galena. The gold was found to have a specific gravity of 15·79, and the following composition: gold, 84·89; silver, 13·99; iron, 0·34; and quartz, 0·43. Several spangles had a peculiarly rich yellow colour, due to a thin film of sesquioxide of iron adhering to their surface.

CHAPTER II.

GEOLOGICAL OCCURRENCE AND MINERALOGICAL ASSOCIATION.

It is probably no exaggeration to say that preconceived notions and hasty theories concerning the formation and geological age of gold have done more to retard the gold-mining industry than to advance it, and that many of the most important discoveries of recent years have been in direct opposition to the dicta of the greatest authorities. This, indeed, is hardly surprising when we reflect what a very small proportion of the earth's crust has ever been examined at all, and observe the absence of uniformity among geologists even in the names bestowed upon the rocks that have been examined. In the belief that our knowledge is still quite inadequate to account satisfactorily for the manner in which metalliferous veins are formed, and to define the laws which govern their formation, no attempt will be made in this volume to promulgate any new theory on the subject, nor to give precedence to any one in particular of the existing theories. The half-dozen most recent opinions of men best entitled to discuss the question will be concisely stated, so far as they deal especially with gold; and this will be followed by a full yet simple categorical statement of the geological formations in which gold has been found, incorporating all details of scientific or industrial value; as well as with a similar account of the various mineral associates of gold, especially with a view to elucidating the character of the association. It is believed that by thus confining remarks to a clear arrangement of ascertained facts, this chapter will be found much more valuable for purposes of reference, and may form a foundation on which to build other facts as acquired, and thus pave the way for future theories and deductions.

Origin and Formation.

The first notable recent attempt to explain the origin of auriferous quartz veins was Henry Rosales' prize-essay, written for the Victorian Government, in 1860. It is substantially as follows:—

"Auriferous quartz lodes are unlike most other lodes, which are 'crevices more or less vertical, caused by contraction during drying, or by metamorphism, or by mechanical disturbance of a rock, this crevice having been subsequently filled up.' They are in their origin anterior to all those forces, some of which accompanied the eruption of granitic rocks, and which have been thoughtlessly applied by some to explain the origin of quartz lodes. The fact that the quartz lodes are of an earlier date than the granite, forces a further investigation of the subject to a remote period of the earth's history, when the granitic rocks, not yet having made their appearance, the Cambro-Silurian beds were still undisturbed in their original horizontal position. The Cambro-Silurian system of Australia presents a series of coarse- and fine-grained sandstone, containing few marks of slaty structure; slaty sandstone of different colours, alternating with bands of slate of perfect cleavage, also of different colours, but generally exhibiting a greenish hue, and white when decomposed. Organic remains seem to be of rare occurrence in this formation. This far and widely spread Palæozoic series of rocks—the waste and refuse of the primitive cooling crust of the earth's surface, was deposited slowly, gradually, and without interruption in horizontal beds, which thus attained the enormous thickness they now present during that protracted period, when peculiar cosmic and telluric agencies, all as yet singularly averse to organic life, were at work. While, however, there are no apparent signs of mechanical disturbances during the long period that elapsed from the cooling of the earth's surface to the deposition of the Silurian and Cambrian systems, it is to be presumed that the internal igneous activity of the earth's crust was in full force, so that on the inner side of it, in obedience to the laws of specific gravity, chemical attraction, and centrifugal force, a great segregation of silica in a molten state took place. This molten silica continually accumulating, spreading and pressing against the horizontal Cambro-Silurian beds during a long period, at length forced its way through the superincumbent strata in all directions; and it is abundantly evident, under the conditions of this force and the resistance offered to its action, that the line it would and must choose would be along any continuous and slightly inclined diagonal, at times crossing the strata of the schists, though generally preferring to develop itself and egress between the cleavage planes and dividing seams of the different schistose beds. Thus were formed in a more or less horizontal position, in all directions, innumerable flakes and extensive sheets of quartz rock, apparently interstratifications as regards their strike, but only apparently such, for they distinctly traverse and intersect the underlie of the slate rocks, being thicker between the schistose planes, and narrower when intersecting them. From the quartz rock started quartz veins, some (β) running almost parallel with, and others (γ) perpendicular to its position, while other veins (δ) shot out in capricious planes and directions. These veins or leaders all thin and run out in comparatively short distances, especially such veins as cut across the slates at the line of the greatest resistance. Simultaneously with the upheaval by the granitic rocks of the Cambro-Silurian slates in average meridional line, the approximately horizontal main quartz belts were upheaved and placed on edge along with the schist strata by this general disturbance. It is in consequence of this change that the quartz belts are apparently interstratified, while in reality, they are merely intersecting. The positions having been altered, what formerly was or approached the horizontal, became perpendicular, and *vice versâ*, so that horizontal sheets of quartz reefs which had been forced between the schistose cleavages and different strata, appeared as almost perpendicular quartz lodes, their strike being conformable to the general meridional bearing of the schist, and the coincident line of upheaval, their underlie intersecting that of the slates to the E. or to the W., the veins (β) which ran parallel, following the main course of the quartz rock, the perpendicular veins (γ) becoming horizontal or flat, while the other veins (δ) would take their respective analogous positions. In the same manner, the horizontal sheets of quartz rock, when upheaved in the medial line of action, would show along their approximate meridional line a varying shoot to the N. or to the S.; a N.E. or N.W. horizontal development of quartz rock would thus necessarily, when upheaved, have its shoot northerly, while a S.E. or S.W. stretch would present a southerly shoot, and a lateral upheaval would, of course, reverse the above order. In quartz lodes where there is no noticeable or well-defined shoot in either direction, it may be inferred that their original development was indifferently either N., S., E., or W.; and this is precisely the appearance which auriferous quartz lodes present in nature to the miner and geologist; they form innumerable more or less perpendicular quartz dykes and extensive quartz rock belts which strike, but with few exceptions, in an approximate meridional line, thus disclosing to view, on a gigantic scale, that remarkable parallelism which, after all, is but a natural feature necessarily consequent on the almost unvarying strike above alluded to. These auriferous quartz lodes intersect the strata of the slate rocks, and are cased with walls of slate and sandstone; they have quartz veins issuing from them in various directions across the country as leaders, flat veins, &c. They sometimes form themselves into irregular masses of veins, at other times they appear as massive bodies of quartz rock which dwindle into strings that serve as the connecting links with some other quartz blocks. These facts go to show that the quartz lodes when forcing their egress often disturbed, fissured, and rent the enclosing schists, the openings so effected being instantly filled by the quartz stone, thus giving rise to those capricious irregular or zigzag shapes vulgarly termed E. and W. veins, &c., which are frequently met with in underground workings.

"But there are other than the cosmic and geological conditions mentioned which prevailed at the time of the origin of quartz lodes, and they also equally indicate the plutonic character of this dyke formation. Under this head is to be reckoned the occurrence of felspar in quartz veins, for it is an established scientific fact that mica, felspar, and amphibole or augite, are all minerals none of which can be formed apart from igneo-chemical action. This single fact would alone go far to indicate the originally molten state of the silica of quartz lodes. Another argument to the same end may be drawn from the fact that the auriferous quartz lodes have exercised a manifest metamorphic action on the adjacent walls or casing; they have done so partly in a mineralogical sense, but generally there has been a metamorphic alteration of the rock. Hence it is that in the immediate contact of the quartz lodes the schist or fragments of it are generally more or less micaceous or altered into their laminæ of mica, crystalline laminæ of nacrit or of chlorite, which has invariably tinged the adjoining quartz with a green colour. Among these minerals is one at times disintegrated which shows the cleavage of orthoclase. There are but few minerals found at the contact of the schist and quartz rocks. This, however, is only natural, for the interchanging rocks were of simple chemical composition. The metamorphic influence exercised by the quartz rocks on the bordering strata is very striking, though it is not easy to distinguish it all over them; it is pre-eminent in the mining district of Tarrangower, where all the quartz lodes are separately checked and walled by distinct accompanying strata of dark siliceous schist or Lydian stone, evidently slate and sandstone schists hardened by the metamorphic action of the quartz lodes, in the same manner as when acted on by igneous or volcanic rocks, apparently changing the physical conditions without altering the chemical quantities. This metamorphic action is observable in the Tarrangower district for many miles. In the Bendigo district, the metamorphic action is also to be seen, quartz rock belts being often carried in between hard ferruginous schists which, however, are generally disintegrated, and do not therefore present any very prominent metamorphic features. In the Ballarat district, the metamorphic action of the quartz lodes may also be detected, although the rocks there are even more disintegrated than at Bendigo; it is not very easy, therefore, to distinguish their mineralogical composition with any tolerable degree of accuracy. The hard, compact, partially disintegrated strata of Ballarat, which separate the quartz belts from each other, may be considered to correspond geologically with the metamorphic siliceous slate of Tarrangower. The same metamorphic action can be traced throughout the districts of Amherst, Avoca, Creswick, &c. Another reason for the igneous origin of the auriferous quartz lodes consists in the mechanical disturbance caused by the protrusion of the quartz lodes themselves. It is to be constantly observed that the strata of the schistose rocks are more or less contorted—that their underlie is variable to the E. or to the W.—that fragments of them are entangled in and metamorphosed by the quartz lodes, and that in consequence the adjacent 'country,' to use a mining expression, is frequently broken up into fragments, forming a breccia of commingled slate and sandstone, whilst the quartz lodes and veins traverse the same country intact and unbroken. The inevitable inference is that the disturbance was caused by the forcible protrusion of the quartz lodes. From the above facts and deductions, it can therefore be maintained that the gangue of the auriferous quartz lodes is of igneous origin, and not the result of the gradual deposition of quartz from a siliceous solution. In addition to the positive arguments already adduced, which base themselves on geological observations, there are also negative ones, the result of scientific deductions, which lead to the same conclusion. Starting from the established fact that silica is soluble in water and watery vapour, during its separation from alkalies, the first considerations which present themselves are in reference to the supply of the great quantity of alkaline silicates, which at that time could only be of a felspathic nature. How under the then existing circumstances could the enormous quantities of water or water-vapours, requisite to dissolve the immense mass of quartz which was to form the innumerable quartz lodes now existing, continuously find their way into the bowels of the earth? The number of these quartz lodes could hardly be attributed to aqueous agency, as a solution contains no intrinsic forcing power, and could therefore have but comparatively few outlets. More than this, the felspathic rocks having been deprived of their alkaline silicates to form silica, there would remain an immense bulk of clay, and the disposal of this residuary mass is not accounted for in any way. It is another weighty consideration also, that the formation of quartz lodes by the deposition of silica, from an aqueous solution, would necessarily involve the production of hydrous silicates, zeolites, hyalite, opal, &c., which are always present in the deposits made by siliceous thermal springs, as in the 'geysers' in Iceland, and indeed in all volcanic eruptions in which there were aqueous vapours: it is so in basalt, &c. These are all minerals which authenticate the presence of water-vapours at the time of their formation, and are to be found in the gangue of many metalliferous lodes, as at Andreasberg; Stronsian, in Scotland; Ciclowa, near Oravicza, in the Bannat; Huelgoet, in Brittany; Kongsberg, in Norway, &c. The quartz lodes of this country show a character quite distinct from that just now referred to; for nowhere are the hydrous silicates, or the other minerals named, to be detected in them; and it is therefore to be inferred that their non-existence demonstrates the impossibility of the origin of quartz lodes being due to an aqueous solution.

"The next question is as to the metalliferous character of the quartz lodes. There are but few metals or metallic minerals to be found in them: they are gold, iron, and arsenical pyrites, the last two in some instances in great quantities; copper-pyrites, zinc-blende, galena, molybdenite, pharmacosiderite, hematite or glaskopf, and malachite; the last three, however, are oxygenated, and are therefore to be looked on only as minerals of secondary formation, the result of the disintegration of the primitive minerals, which are arseniurets and sulphurets. These minerals ascended simultaneously with the quartz; and the contemporaneous formation of the quartz gangue, arseniurets, and sulphurets implies the forcing up of these minerals in a sublimated state. The heat of the molten silica would necessarily volatilize the gold as a vapour of purple colour, and would also sublimate the arseniurets and sulphurets, which are all volatilizable without being decomposed, at a much less temperature than gold, air being excluded. They are found decomposed only near the surface. Thus the purple fumes of metallic gold and sublimated vapours of the arseniurets and sulphurets of other metals, entering the quartz gangue, permeated it as gaseous vapours, forming veins, shoots and streaks, interlacing the gangue in the direction of its stretch, penetrating also into the recesses of the quartz veins and leaders, the gold being precipitated in gold-leaves, film, &c., on comparatively cold bodies, such as the sides of the lodes, or entangled pieces of schist, and accompanied by the sulphurets and arseniurets. The sulphurets, arseniurets, and other volatile metals influenced the volatilization of gold, and in this way it was carried into and lodged in the crevices, joints, and sides of the lodes, where it could not have reached unless accompanied by the sulphurets and arseniurets. Hence we find gold in its metallic state mixed mechanically with iron- and arsenical pyrites; sometimes it is even perceptible to the naked eye, at other times it is not; and it is also found mixed with galena and zinc-blende. Indeed it is scarcely possible to find either of these two minerals without at the same time finding gold in contact with them. Of the minerals enumerated, iron- and arsenical pyrites are found in large quantities in the quartz gangue; but copper-pyrites, galena, and zinc-blende, are seldom found, and then in insignificant quantities. It is to be remarked that the affinity of these different minerals is according to the following scale—first, galena, then and almost if not quite equally, zinc-blende, arsenical pyrites comes next, and iron-pyrites follows; and therefore gold is contained in the gangue along the shoot of these metalliferous ores; but where the gangue is far apart from the metalliferous indications, it is generally barren. On this theory, it is not difficult to account for the flat leaders and the running out of the quartz stretches, now the caps of the reefs, being often richer than the rest of the gangue, or to account for the poverty or richness of reefs, when they suddenly become contracted for a certain length, conformable to the greater or less opportunity offered to the gold to precipitate according to the physical circumstances, such as mechanical impediments, change of temperature, &c.

"It has been attempted to explain the origin of gold as being the result of precipitation by iron from its solution, under the influence of electricity. Without entering into the chemical part of this theory, it may be sufficient to remark that the theory in question is one-sided, only accounting for the formation of gold, but not of the sulphurets which would be decomposed. Strictly, then, the simultaneous deposition of gold, sulphurets, and arseniurets, goes to prove chiefly that a very feeble electrical agency was at work in the formation of the quartz lodes. However, it was owing to the subsequent electrical influence, at first an electro-chemical one evolved by the disintegration of the primitive minerals, that even remote substances were decomposed, and that new combinations were formed—the secondary minerals, such as cube ore, pseudomorphous hematite, &c.; their elements being transferred by electrical currents even through moist non-conducting solids, and in some cases during the process they were deprived of their chemical properties, or in other ways influenced by electric agency. It is to the action of these currents of electricity, whose intrication Fox has so well described, that the present partially or entirely disintegrated state of the upper levels of the quartz lodes is chiefly to be attributed. From the igneous origin of auriferous quartz lodes and metallic ores, it would be correctly assumed that the gangue would exhibit a homogeneous character; this, however, is not always the case, although it is so generally. Where it is not so, it is no doubt due to the subsequent reopening of the gangue fissures, more recent protrusions of quartz rock having almost disconnected the more ancient veins, or else formed a new body in their midst, and so giving to the whole, for some distance, a flaky, laminated, or seamy appearance, which is greatly increased by entangled schistose fragments and veins of metallic substances, either decomposed or otherwise. But that order of deposition of different substances, corresponding with the faithful parallelism from the sides of the lode towards its centre, cannot be found, though it is a remarkable feature in many veins containing carbonates of lime, iron, &c. Werner first called attention to this striking arrangement, of which Weissenbach has given numerous examples, and which was evidently caused by the agency of water. Thence it is that the seamy appearance in some portion of the quartz lodes does not point to the conclusion of an aqueous origin, for it is irregular, however apparently otherwise at first sight, as it does not fulfil the above-described conditions of parallelism. In some districts the quartz lodes have been disturbed by felspathic or igneous rocks, forming dykes of a more recent epoch. Hitherto the felspathic dykes of Bendigo and Maryborough have received the most attention; in the former district, they are found at times traversing the quartz lodes, following their strike, or faulting them; and in other cases, separating their course from them, they crop out on the surface. They are greatly disintegrated, so much so that it is not possible at present to give their mineralogical composition with accuracy, or to determine their geological age beyond what has been already advanced. They do not seem to contain zeolites, but appear to be intimately connected with the subsequent changes in quartz lodes, such as the reopening of the quartz veins, and also the occurrence of large masses of arsenical pyrites, which, and it is a most interesting fact, as it shows the connection of this metalliferous ore with heat, contain a felspathic mineral, as already stated. In the latter district, they have been called quartz-porphyry, and seem to be of precisely the same character as those of Bendigo; they disturb and are connected with the quartz lodes in a similar manner, and are in a state of partial disintegration; their mineralogical character may be somewhat different, as their name—quartz-porphyry—indicates. It is, nevertheless, probable that both these igneous rocks are contemporaneous. At Ballarat no igneous dykes have been yet observed, either on the surface or underground; thus disturbances as 'faults' are of rare occurrence; up to the present time, none of any consequence have been found, and it is a remarkable fact, also, that arsenical pyrites has not been found there, either in small or large quantities, as at Bendigo, Tarrangower, &c. In the sandstone walls of a very few quartz lodes, the empty impressions of arseniuret of iron have been found. Would the absence of igneous dykes not seem to presuppose that the quartz lodes have not been reopened, and that, therefore, arseniuretted masses of auriferous character could not have been injected? And might not the comparative poverty of the Ballarat quartz lodes be also thence presumed? From what has been stated as to the theory of the igneous origin of auriferous quartz lodes, it may be logically deduced that the presence of sulphurets and arseniurets in a quartz lode is an empirical test of its comparative auriferous character; that the appearance of igneous dykes in connection with quartz lodes, and contemporaneous with those mentioned, would give a more auriferous stamp to any district; and that auriferous quartz lodes are to be expected, intersecting the schistose formation, at any depth. The last statement is borne out by the following considerations: first, it can be easily imagined, if the enormous abrasion be taken into account, how deep the present surface with its yet auriferous quartz lodes, must have been under that which existed before abrasion took place; again, the granite which simultaneously upheaved the Cambro-Silurian and auriferous quartz rocks, disturbed the thick schistose formation with such gigantic force that it contorted and placed the beds on edge, thereby causing enormous convulsions and faults, on a scale too grand to be noticed by the miner; and it is evident that in some instances strata of the schistose and quartzose formation which, before the upheaval of the granite, were far below the formerly existing surface, have been disclosed by that upheaval, and that these strata contain quartz lodes in no wise less auriferous. It may, therefore, be maintained that to as great a depth as the quartz miner can ever penetrate, he will find auriferous quartz lodes, and that deeper still there are others equally auriferous."

Another view of the question is taken by Richard Daintree, in his report on the geology of the district of Ballan, Victoria, in 1866, when discussing whether the drifts underlying the old amygdaloids of Bacchus Marsh are theoretically likely to contain drift-gold. The problems proposed for solution were "(1) the age and origin of quartz reefs, (2) and whether the gold is contemporaneous with their formation. To answer the first question, in regard to age, he sought sections where strata of determined age containing quartz reefs are seen overlaid unconformably by other sedimentary strata of known age. Such are to be found in the Werribee gorge, where the quartz strings and reefs traversing Silurian slates, &c., cease abruptly at the junction of the 'Lower Mesozoic,' from which may be inferred that these quartz reefs at least were formed prior to the superincumbent strata. In Gippsland, again, Upper Devonian conglomerates, with their associated claystones and sandstones, enclosing *Lepidodendra*, &c., are barren of quartz reefs, while the Silurian on which they rest have reefs well defined." He then quotes Hartt, on the "Gold of Nova Scotia of pre-Carboniferous age," as follows:—

'At Corbitt's Mills, about 4 miles N. of Gay's river, Colchester county, Nova Scotia, auriferous clay-slates of the same character as those of the other gold-districts of the province, are overlaid unconformably by nearly horizontal beds of grey and red conglomerate, grit, and sandstone, of Lower Carboniferous (probably lower coal measures) age. At the mills, these last are only a few feet in thickness. They in turn are overlaid by a mass of drift, and by beds of stratified sand and clay of variable thickness. As to the Carboniferous age of the conglomerate and sandstones there can be no doubt. They cannot be Silurian, for they overlie unconformably rocks of this age. They are totally unlike any Devonian rocks occurring in the province, while they agree perfectly with the Lower Carboniferous conglomerates and sandstones of the Carboniferous basin on the margin of which they lie. They contain a few ill-preserved fossil plants like those found in similar Carboniferous beds. Between the Carboniferous and the Drift the only formation occurring in Nova Scotia is the New Red Sandstone, to the rocks of which the beds under consideration bear no resemblance. They cannot be of Drift age, for their fragments form rounded boulders in that deposit. They show no signs of having suffered metamorphism. The lower part of the beds of conglomerate or grit, at their junction with the slates, is richly auriferous, the gold occurring principally in the form of flattened scales, sometimes $\frac{1}{4}$ in. in diameter, disseminated through the rock. I have seen many fragments of the conglomerate, not 1 cub. in. in size, on the surface of which 20 or 30 scales of gold could be counted with the naked eye. Gold has been washed from the drift overlying the conglomerate. The source whence the gold was derived was doubtless quartz veins in the clay-slates. Only one vein, about $\frac{1}{4}$ in. thick, has been discovered beneath the conglomerate. It is richly auriferous, and has a strike of about N. and S., and a dip of 70° E. Non-auriferous quartz veins are very numerous in the slate hills of the vicinity. That this vein is older than the Carboniferous strata is plain from its ending abruptly at the junction with the slates. From the above facts, I think there can be no doubt that the gold of Corbitt's Mills is of pre-Carboniferous origin, and since the gold of that locality was derived from strata precisely similar in character to those of the other gold-regions of Nova Scotia, and which strata are but the reappearance northward of the gold-bearing rocks of the gold-fields of Renfrew and Oldham, and of the metamorphic band of the Atlantic coast, I think that the pre-Carboniferous age of the gold of Nova Scotia is clearly indicated. It is a very generally accepted theory, propounded by Sir Roderick Murchison, that whilst gold is confined to Lower Silurian strata, it did not make its appearance therein until just before the time of the Drift. As the gold of Nova Scotia was probably introduced into or assumed its present form in the quartz veins at the time of the metamorphism of the Silurian rocks, which metamorphism was pre-Carboniferous, I have doubted the correctness of this theory. The occurrence of gold in the Carboniferous rocks of Corbitt's Mill shows that it is not to be applied to the province of Nova Scotia.'

"On Keelbottom Creek and Star river, tributaries of the Burdekin river, in the district of North Kennedy, Queensland, is a great thickness of Devonian rocks, resting on, and no doubt the cause of metamorphism in, underlying gold-bearing gneiss, mica-schists, and hornblende slates. These are associated with very thick beds of quartz rock, rarely with quartz reefs; though traversed with innumerable thin strings and veins of quartz, such reefs and veins never pass into the Devonian series. Although the gold is most abundant in the loose drift resting on the metamorphic rocks, still, where Devonian conglomerates occur, more or less alluvial gold is found in their débris, even where an outcrop of metamorphic rocks is many miles distant. The geological survey of California has ascertained 'that a large portion of the auriferous rocks of California consist of metamorphic Triassic and Jurassic strata.' It is evident that the reefs in these rocks are more recent than those of Hartt in Nova Scotia, or than those of the Werribee gorge, or the Upper Burdekin.

"No subject has perhaps been more discussed than the formation of mineral veins; laying claim to no original ideas on the subject, I shall simply bring forward the published statements, which most coincide with the results I have arrived at by independent observation. I had long ago come to the conclusion, that most, if not all, the gold in the quartz reefs was derived from the rocks in which these reefs occur. That the strata themselves received their supply of gold at the period of their deposition from the ocean in which they were deposited. That organic matter, and the gases generated therefrom on decomposition, sulphuretted hydrogen, &c., were the cause of the precipitation; and that the amount of metallic deposit was in proportion to the amount of organic matter deposited with the oceanic sediment. That subsequent plication and desiccation of the sediment caused fissures, into which the mineral waters percolating the boundary rocks flowed and were decomposed, and their mineral contents were precipitated, possibly by magnetic currents, thus causing mineral veins.

"Sir W. Logan says:—

'The observations among the gold-bearing rocks of the Southern States seem to show that the precious metal was originally deposited in the beds of various sedimentary rocks, such as slates, quartzites, and limestones; and that by a subsequent process, it has been, in some instances, accumulated in the veins which intersect these rocks. The formation of these veins would seem to be subsequent to the Silurian period.'

"Again, T. Sterry Hunt says:—

'The reducing power of organic matter is further shown in the formation of metallic sulphurets, the reduction of sulphates having precipitated in this insoluble form, the heavy metals—copper, lead, and zinc—which, with iron, appear to have been in solution in the waters of early times; but are now, by this means also abstracted from circulation, and accumulated in beds and fahlbands, or by a subsequent process have been re-dissolved and deposited in veins. All analogies lead us to the conclusion, that the primeval condition of the metals and of sulphur was like that of carbon, one of oxidation; and that the vegetable life has been the sole medium of their reduction.'

"And as a corollary to the same ideas, expressed in different words, the same author says:—

'The intervention of intense heat, sublimation, and similar hypotheses, to explain the origin of metallic ores, we conceive to be uncalled for. The solvent powers of solutions of alkaline carbonates, chlorides, and sulphurets, at elevated temperatures, taken in connection with the notions above enunciated, and with De Senarmont's and Daubrée's beautiful experiments on the crystallization of certain mineral species in the moist way, will suffice to form the basis of a satisfactory theory of metallic deposits.'

"Having now considered the age and origin of quartz reefs, let us turn to the other question of contemporaneity of reefs, and their associated gold. Let us first consider if solution and re-precipitation of gold is still going on. We can then better form conclusions on this subject. In testing a solid mass of iron-pyrites, given me by the Director of the Geological Survey, gold was found throughout. The mass retained the structure of a tree-stem, and was a replacement of the organic structure by pyrites, and had been taken from the Ballarat drift. The same experiment on another tree-stem, taken from the same drift, was repeated by Newbery, the Geological Survey analyst, with a like result. Unless this gold was carried in a soluble form into the pores of the wood, and there precipitated with the pyrites, it would be difficult to account for its presence. Foord, the well-known chemist and metallurgist of Melbourne, has repeatedly informed me that, in operating on the St. Arnaud silver-ores with hyposulphite of soda, and precipitating the dissolved metals from the solution, he had usually found that an appreciable amount of gold had been dissolved with the silver, indicating that in that mine, at least, gold may exist as an ore.

"Whether this fact points to the real solvent of the gold and silver precipitates, from their first storehouses in the sediments to their accumulation and re-precipitation as metal in the reefs, is worthy of consideration; certain it is, that when found in the sediments themselves, the noble metals are usually associated with sulphur compounds, iron-pyrites, &c., and there is no reason why hyposulphites of the alkalies should not be formed in the mineral waters percolating these strata. At the same time, it is possible the St. Arnaud case may indicate more the possibility of gold as a chloride combined with chlorobromide of silver.

"In whatever direction we look for the cause of the original precipitation and re-solution for after-deposit in mineral veins, we must never lose sight of the fact that the first agent must have been potent to precipitate both gold and silver, and the second to re-dissolve the united precipitates, as no gold has yet been found in nature unalloyed with silver. That sulphur compounds have played an important part in the reactions which we have endeavoured to explain is evidenced by the fact that scarcely ever has pyrites taken from the Silurian slates of Sandhurst, Maryborough, and other localities, failed to yield gold.

"It is a point of great interest to determine the constituents of Victorian mine-waters, as tending to throw light on such questions as these introduced, and as to whether the large nuggets found in the drifts have been built up by continuous aggregation of precipitate from mine-water. Microscopic examination of thin sections of such nuggets should be obtained. It should also be ascertained if they enclosed foreign material. That the waters percolating our drifts have, in many instances, a strong solvent action on some metals and metallic oxides, we have constant evidence in seeing the blue slates of the hill-slopes, where covered with drift in the valleys, converted into white pipe-clay. Was this solvent carbonic acid, or have we at times a stronger acid in operation capable of acting on silver, and so affording a reason for the fact that the alluvial gold of a district usually assays higher than the reef-gold of the same district?

"Sufficient evidence has, I think, been shown, that, up to comparatively recent times, solution and re-deposit of gold and silver have taken place; although the main concentrated deposit occurred with the accumulation of the quartz itself, in the reefs, still much of the 'casing' gold on the walls of reefs may be of subsequent deposit. If, then, it is a logical deduction from what has preceded, that auriferous quartz reefs have derived their minerals from the bounding rocks, and that auriferous quartz reefs may be of all ages, how shall any one assert that drift-gold may not be found in any sedimentary deposit, derived from rocks traversed by auriferous quartz reefs? At the same time, it is likely to be rare that workable gold-deposits will be found in any marine beds derived from pre-existing rocks, unless entirely made up of the débris of such auriferous rocks. The Nova Scotia Carboniferous conglomerates answer this condition, and are worked, according to Hartt, to a profit. In Victoria, no strictly marine sediment has yet been found to contain workable gold-drifts. All our Tertiaries in which marine fossils have been found, also the 'Lower Mesozoic' of Bacchus Marsh, and the Mesozoic carbonaceous of Otway, Cape Patterson, &c., are composed of sediments of various rock formations. We have as yet no evidence to prove that any workable auriferous drift deposit, of Victoria, has been swept by either of the oceans which deposited strata containing marine fossils in other localities. This seems also to be the case in California. Whitney, says:—

'The vast Tertiary formations on the flanks of the Sierra Nevada, so important as being the locality of the hydraulic mining operations, are not of marine origin, as has been so often asserted. . . . In the first place, these deposits are not of marine origin, as is proved by the fact, that, although frequently found to contain impressions of leaves, masses of wood, and imperfect coal, and even whole buried forests, as well as the remains of land animals, and, occasionally, those of fresh water, not a trace of any marine production has ever been found in them.'"

The next important contribution is Wilkinson's paper on the Theory of the Formation of Gold-nuggets in Drift, written in 1866.

"It has hitherto been a moot question, and one which has elicited no small degree of discussion, respecting the occurrence of larger nuggets of gold in the drifts than have yet been discovered in any quartz reef; and that alluvial gold is generally of a higher standard than that obtained from the reefs.

"Many theories have been introduced to account for these phenomena: among them is one which does not appear to have received that amount of attention it evidently merits. I allude to that advanced by Selwyn, the Government geologist, suggesting the probability of gold existing in solution in the mineral water permeating the Silurian rocks and the gold-drifts; and that this water in its passage through the drifts, became by some unknown means decomposed, influencing the precipitation of the gold, which concreted, so to speak, around the most congenial nuclei presented to it, such as the particles or pieces of reef-gold existing in the drifts, or any other metallic substances for which it had an affinity.

"Daintree, formerly of our Geological Survey, had on one occasion prepared for photographic use a solution of chloride of gold, leaving in it a small piece of metallic gold undissolved. Accidentally some extraneous substance, supposed to be a piece of cork, had fallen into the solution, decomposing it, and causing the gold to precipitate, which decomposed in the metallic state, as in the electro-plating process, around the small piece of undissolved gold, increasing it in size to 2 or 3 times its original dimensions.

"Considering this accidental experiment of Daintree's as in some measure bearing out Selwyn's hypothesis, I was induced to make a few simple experiments.

"Using the most convenient salt of gold, the terchloride, and employing wood as the decomposing agent, in order to imitate as closely as possible the organic matter supposed to decompose the solution circulating through the drifts, I first immersed a piece of cubic iron-pyrites taken from the coal formation of Cape Otway, far distant from any of our gold-rocks, and therefore less likely to contain gold than other pyrites. This specimen (No. 1) was kept in a dilute solution for about 3 weeks, and is completely covered with a bright film of gold. I afterwards filed off the gold from one side of a cube crystal to show the pyrites itself, and the thickness of the surrounding coating, which is thicker than ordinary note paper. If the conditions had continued favourable for a very lengthened period, this specimen would doubtless have formed the nucleus of a large nugget. Crystals of gold have been found to contain nuclei of brown iron-ore and undecomposed iron-pyrites.

"No. 2 specimen contains iron-pyrites, and was immersed in a solution of about 4 gr. of the chloride of gold to 1 oz. of water; in a short time, however, it was found that in such a strong solution, the pyrites began to decompose; but after diluting to about 2 gr. to 1 oz. of water, this decomposition apparently ceased, and metallic gold deposited wherever a particle of the sulphide existed, alike in crevices as on the surface of the quartz, and also in a remarkable mammillary form. This was in the solution for a week.

"No. 3 contains iron-pyrites and galena, on both of which the gold has deposited, so that I cannot now distinguish one sulphide from another. It remained in a solution of 1 gr. of chloride to 1 oz. of water for 8 days.

"Nos. 4 and 5 are similar specimens to the last mentioned, the same strength of solution being used; but they were only dipped half-way into it, so that the immersed part coated with gold may be compared with the other half on which the pyrites remains unaltered.

"I may here remark that a weak solution produces more perfect results than a strong one; with the latter, the sulphides are partly decomposed, and the gold is covered with a dark-brown powdery film, as observed in some of the above specimens. This film does not prevent the growth of the gold in the solution, and it may easily be rubbed off.

"Nos. 6 to 13.—Iron-, copper-, and arsenical pyrites, antimony, galena, molybdenite, zinc-blende, and wolfram were treated in the above manner with similar results.

"Brown iron-ore and quartz covered with peroxide of iron were also tried in the same way, but the gold was deposited only as a fine metallic powder.

"In the above experiments, a small chip of wood was employed as the decomposing agent. In one instance I used a bit of leather. All through the wood and leather, gold was disseminated in fine particles, and when cut through, the characteristic metallic lustre is brightly reflected.

"The first six of these sulphides were also operated upon simply in the solution without organic matter, but they remained unaltered.

"Iron-pyrites was tried with metallic copper, zinc, and iron as decomposing agents; but metallic gold was deposited only as a fine powder, which settled at the bottom of the vessel.

"From these experiments, it would appear that organic matter is the necessary chemical agent to decompose a solution of the chloride of gold, in order to precipitate the gold as a coherent coating around a nucleus presented to it; and that so far as we have yet tried, iron-, copper-, and arsenical pyrites, galena, antimony, molybdenite, blende, wolfram, and metallic gold, constitute especially favourable nuclei to demonstrate this chemical reaction.

"Organic substances, such as fragments of wood, roots of trees, &c., exist abundantly in the gold-drifts. It remains therefore a point of great importance to decide whether gold is actually in solution in the meteoric water circulating through our rocks and drifts. I am not aware of direct experiments having been made to solve this question, but that gold will most probably be found, is indicated by analysis made by Daintree (already quoted on p. 757, line 10).

"I referred to the mammillary form the gold assumes in No. 2 specimen, which appears to be analogous to that presented by the surface of nuggets. Analogy, however, though generally a truthful guide, if relied upon too implicitly in outward semblances, may lead to erroneous conclusions. Nevertheless the striking similarity in the surface of the artificial production to that of the natural gold is a point worth noticing. For if the form of the latter is the result of abrasion of its surface by the material carried along by the streams that once swept down the courses of our old 'leads,' then our analogy will not hold good. Yet when we have no evidence of the existence of such large nuggets in the reefs, and this theory introduces a means of producing results like those in nature, we are justified, in the absence of such evidence, to attribute these results to analogous causes. Otherwise to what origin shall we ascribe the presence of gold in pyrites that has been formed in wood imbedded in the auriferous drifts, and the fact that sometimes gold encloses a nucleus of brown iron-ore &c., unless it was deposited from solution?

"That gold may be greatly purified by dissolving and reprecipitating it, is strong evidence in favour of the theory attributing to a similar cause the greater purity or higher standard generally of alluvial than reef gold.

"It would be premature for me to speculate further on the hypothesis of the growth of gold—the formation of nuggets in the drift, on which the above recorded few simple experiments may perhaps throw some light—until the result of more comprehensive and systematic experiments which are now being conducted by Newbery are known. In conclusion, I beg to acknowledge my indebtedness for some points in the foregoing to a Report on the Minerals of Victoria, just completed, by G. H. F. Ulrich, of the Geological Survey."

The experiments just alluded to are those described by Prof. J. Cosmo Newbery, in his paper on the Introduction of Gold to, and the Formation of Nuggets in, the Auriferous Drifts, written in 1868. He says:—

"Before describing my experiments and their results, it may be well for me to give an abstract of the arguments used for and against the denudation theory and in favour of what seems to some a rather ludicrous idea—the growth of nuggets in the drifts.

"Through the kindness of Mr. Ulrich, I have been able to read the latest ideas of the eminent chemical geologist, Prof. Bischoff, from whom I shall freely quote.

"That some portion of the gold found in the drifts has been derived from the quartz reefs at the same time that the reefs themselves were formed, there can be no doubt; but the absence of large nuggets in the reefs and the marked difference that exists between much of the drift gold and that from the reefs, tends to make us believe that some portion of it had some other origin, or was transferred from the reefs to the drifts by some means other than denudation. Even if we admit that the large nuggets may have been derived from the reefs by denudation—(for there is a theory that the reefs were much richer in the portions removed to form the drifts, than they are as they now exist)—we must remember that the nuggets consist of nearly the heaviest known matter, offering but a very small surface of attack, when compared with the other materials acted on by the same force and at the same time; it therefore appears strange that these heavy masses should be found at such great distances from any known reef, as nearly all the large nuggets have been. Another point which attracts attention is, that they are sometimes found in the sand overlying the gravel, which is quite inexplicable, if they ever were in motion with the rest of the drift, which usually has a regular arrangement from top to bottom: first clay, then sand, and fine and coarse gravel.

"These objections to the denudation theory are not easily explained away. And then comes the great fact that gold is contained in the iron-pyrites which is found in the drifts, assuming the form of roots and branches of trees, and also replacing the carbonaceous matter of the other drift-wood. Every sample of this pyrites that has been examined has been found to contain gold: in some instances, in a quantity equal to 40 or more oz. per ton, and this in samples in which no particles could have collected in crevices or cracks.

"This proves that gold did exist in the meteoric waters which deposited the pyrites in Tertiary times.

"Based on these arguments, Selwyn, some years ago, advanced the hypothesis, 'That nuggets may be formed and that particles of gold may increase in size through the deposition of gold from the meteoric waters percolating the drifts, which water, during the time of our extensive basaltic eruptions, must have been of a thermal and probably of a highly saline character, favourable to their carrying gold in solution.'

"As Ulrich points out in his essay on the Mineralogy of Victoria, this view of the character of the meteoric waters in earlier times receives aid from the fact that on our western gold-fields only, where tremendous basaltic eruptions have taken place, all the large nuggets have been found, while on the eastern and northern fields, where basaltic rocks are wanting, or only of very limited extent, the gold is usually fine, and nuggets of more than 1 oz. in weight are very rare.

"That gold does exist in solution in some saline waters of the present day has been proved by several analyses; and Daintree found gold in solution in water taken from a mine in this colony.

"Further proof of gold having been in solution at a comparatively recent date, I found when examining the pebbles of the Miocene drifts; they are chiefly quartz, and are coated over with manganiferous brown iron-ore, in which I found gold, though I never could detect any in the pebbles when their surfaces were carefully cleaned.

"What the gold salt was, whether a chloride, silicate, or sulphide, we have no means at present of ascertaining. And as it may have been in the same solution that deposited the pyrites, which probably contained its iron in the form of protocarbonate with sulphates, it was not easy at first to imagine any ordinary salt of iron; but this I find can be accomplished with very dilute solutions in the presence of an alkaline carbonate and a large excess of carbonic acid, both of which are common constituents of mineral waters, especially in Victoria. This is true of chloride of gold, and if the sulphide is required in solution, it is only necessary to charge the solution with an excess of sulphuretted hydrogen; in this manner, both sulphides may be retained in the same solution, depositing gradually with the escape of the carbonic acid.

"Prof. Bischoff has suggested the occurrence of sulphide of gold in meteoric waters, and by experiment he found that it was slightly soluble in pure water. Once formed and present in the water, it is, like all other gold salts, easily decomposed. In an experiment I have made, the sulphide of gold was held in a solution by a small quantity of an alkaline bicarbonate. A cube of iron-pyrites and a chip of wood were introduced, and in a few days small irregular grains of metallic gold were deposited on the pyrites.

"What part the organic matter took in the reaction is not clear, but the gold was not deposited without it.

"In Chas. Wilkinson's paper (see pp. 759–61), a series of experiments are described in which gold was deposited in the metallic form upon a nucleus, from a solution of the chloride by the reducing agency of organic matter, the nuclei being either gold itself, or iron-, copper-, and arsenical pyrites, galena, zinc-blende, sulphide of antimony, &c. Organic matter has long been known as an agent for precipitating gold in the metallic state from its solutions.

"Rose states that oxalic acid precipitates it in metallic laminæ. This I have failed to produce. When boiled with a solution of chloride, I got purple and red precipitates; but when allowed to remain at the temperature of the air for some hours, a film of gold floated on the surface of the liquid, and the bottom and sides of the vessel were gilded. Tartaric, citric, and other organic acids have much the same effect. With wood, bark, charcoal and like substances, the reduction is much slower. No carbonic acid is seen rising, and the gold is deposited in the pores of the reducing agent, if the solution is dilute. But it was not known until the experiment of Daintree, and the following ones made by Wilkinson, that this deposit would take place on a nucleus, and be continued as long as gold remained in solution. If this action went on in the drifts, it would account for the greater purity of the gold and for the nucleus of brown iron-ore so often found in nuggets and crystals. Strong solutions of gold immediately began to decompose the pyrites, and interfere with the regular deposition of gold. By a strong solution, I refer to one containing more than 1 gr. of chloride of gold to 1 oz. of water. A weaker solution than this also decomposes the pyrites, but so slowly as not to interfere with the deposit taking place regularly; all the other sulphides are also decomposed. In the experiment in which galena was used as a nucleus, this decomposition was best marked. Somewhat more than a year ago, I placed a cube of galena in a solution of chloride of gold, with free access of air, and put in organic matter: gold was deposited as usual, in a bright metallic film, apparently completely coating the cube. After a few months, the film burst along the edges of the cube, and remained in this state with the cracks open, without any further alteration in size or form being apparent. Upon removing it from the liquid a few days ago, and breaking it open, I found that a large portion of the galena had been decomposed, forming chloride and sulphate of lead, and free sulphur, which were mixed together, encasing a small nucleus of undecomposed sulphate of lead. The formation of these salts had exerted sufficient force to burst open the gold coating, which upon the outside had the mammillary form noticed by Wilkinson, while the inside was rough and irregular, with crystals forcing their way into the lead salts.

"Had this action continued undisturbed, the result would have been a nugget with a nucleus of lead salts, or, if there had been a current to remove the results of the decomposition, a nugget without a nucleus of foreign matter. If, instead of galena, we had had a piece of pyrites to start with, the decomposition would have gone on in the same way, but the result would have been brown iron-ore in place of lead salts. This decomposition gives a very simple means of accounting for the oxide of iron, so often found in the nuggets and crystals of gold, the latter especially, as shown by the experiments of the late Dr. Becker, by cutting them in halves, and by their established low specific gravity, and their loss in weight suffered in smelting.

"Finding the brown iron-ore of the Miocene drifts contained gold, I was led to suppose that though I could not make gold deposit on it, I might succeed in making them deposit together, which was the case. I arranged a mass of sand, with chips of organic matter in it, in a vessel, and slowly filtered through it a dilute nearly neutral solution of sesqui-chloride of iron, containing a few drops of chloride of gold, and as it passed through repeated the dose. This continued for some weeks without any appreciable change taking place; but after some months, thin bands of hydrated sesqui-oxide of iron began to form across the mass about the centre, parallel with the surface. As they increased in size, they assumed a botryoidal appearance, like the 'ferro-manganese ore' which occurs in the quartz reefs, and in many parts were coated with a bright film of metallic gold. Every further addition to the mixed solution produced another layer of oxide and gold, so that in time it appeared stratified. If the gold had been continued alone after once having started its deposition, the result would have been the same as in the case of the decomposition of pyrites. On the other hand, if the iron solution was in excess after a deposit of gold had been formed, it would have produced what is so often found in the alluvial workings, a nugget coated with iron-ore, commonly known as 'black gold.'

"This mixed solution is one which we should not expect to find in nature, but there is no difficulty in supposing the transfer of gold with iron that would deposit as oxide, even, if we need to introduce carbonic acid. If a solution of sesqui-chloride of iron and chloride of iron are heated together, the whole of the gold, in a very finely divided state, with a portion of the iron as sesqui-oxide, is deposited in a brownish-yellow precipitate.

"Though the processes I have described will account for the formation of nuggets, it does not account for the appearance of gold in pyrites. I have examined about 100 samples, in none of which do I find any tendency on the part of the gold to assume the form of a coating, it being usually in irregular grains, and small octahedral crystals, seldom to be detected, even with the aid of the microscope, until nearly all the pyrites has been oxidized and decomposed. In a few exceptional cases, pieces have been found projecting; but all tends to prove the priority of the deposition of the gold, and that instead of pyrites having formed a nucleus for the gold, the reverse has in the majority of instances been the case.

"It may also have been the first to deposit in the drift-wood, for in all the experiments by Wilkinson and myself the organic structure became so impregnated with gold that when ignited (so as to burn off the undecomposed organic matter) a golden model remained. Flies, which fell into some of my experiments, and were useful in keeping up a supply of fresh organic matter, became so thoroughly impregnated that in some cases the finest hairs on their backs and legs were to be seen in bright gold after ignition. Conditions such as these (before ignition) would be very favourable to the formation of pyrites, offering to a ferruginous water containing sulphates, a reducing agent, and congenial nuclei for the crystals to form on. Crystalline gold is very easily made, by simply introducing a chip of wood into a solution of chloride of gold, containing 5 or 6 per cent. of the salt. The crystals are first seen on the surface of the liquid as a thin film, which, as it grows heavier, falls to the bottom, where it assumes a moss-like appearance; if this is examined under the microscope, it will be found to be a network of octahedral crystals, resembling very closely the gold-crystals from pyrites. These crystals have been repeatedly made in a carefully-closed vessel, so that no dust might enter, and falling on the crystals form nuclei for them. With these crystals I sometimes found irregular pieces of gold, some in places showing planes of octahedrons. In these experiments, as in all the others, organic matter is necessary, the action ceasing when it was removed, starting again immediately with a fresh addition.

"These experiments are based on the assumption that the gold exists in the pyrites in the metallic form, and not as sulphide, as has been supposed to be the case by some. Daintree got gold in solution by digesting some of the pyrites from Clunes in sulphide of ammonium; but I have always failed to prove the presence of it as negative evidence against it. I have the result of experiments made by digesting the pyrites with an oxidizing agent, washing the residue free from impurities, weighing the gold, and comparing the result with that got from a portion of the same sample made by the ordinary fire assay and finding that they agreed.

"If sulphide of gold had existed in the metallic waters, we might expect in some cases to find it; but, as before noticed, it is so easily decomposed, that it is not possible for much to have resisted the heat caused by the basaltic eruptions.

"I have experiments now in progress which contain the sulphides of iron and gold in solution, but up to the present time without any result, in this direction. Like some of the others I have spoken of, they may require a year or more to accomplish the end wished for.

"Prof. Bischoff suggests silica as the medium for the transmission of gold to the quartz reefs. Gold, as he points out, certainly has a great affinity for silica, always being found in connection with it in mineral veins in the drifts and even in the pyrites, where I have always found silica as grains, and minute nearly perfect hexagonal crystals; the occurrence of which I have always been at a loss to account for.

"The Professor's experiment is a very instructive one. He reports it as follows:—'On adding to a solution of chloride of gold a solution of silicate of potassa, the yellow colour of the former disappears. After ½ an hour the fluid turns blue, and in time a gelatinous dark-blue precipitate appears, which adheres firmly to the vessel. After the lapse of some days, moss-like forms are to be seen on the surface of the precipitate, like an efflorescence; on exposure to sunlight, no reduction takes place, but after the lapse of some months, if the precipitate is allowed to remain undisturbed under water, a decomposition takes place, and in the silicate of gold, appear minute partly microscopical specks of gold.'

"If this is the method by which the gold reached the lodes, as the Professor argues, the origin of the silica may also be that of the gold. The origin of the former we now believe to be the silicates of the rocks, by the decomposition of which by mineral waters the silica is conducted to the lode cracks. In these silicates, we have therefore to look for gold, and it is possible that it is contained in them as silicate. To prove this is almost impossible, for if we even found the gold, it would be in a quantity too small to determine whether it was in combination or not.

"Silicate of gold is extremely insoluble in water, but if we assume that its solubility is in the same ratio to the solubility of silica as the gold of even our richest reefs is to the silica in the reef, we shall find no difficulty in admitting that silicate of gold may exist in solution.

"In several instances, an amethystine colour has been observed, both in the quartz reefs and in the wash-dirt of the drifts. Aplin tells me that he observed it in a lead of wash-dirt near Beechworth. When pieces of the clay so coloured were first broken out, no gold was to be seen; but after exposure to the light and air for a short time, the colour disappeared, and it was seen to be full of very finely divided gold. Ulrich also tells me that this colour and phenomena were observed by Clement, a successful quartz miner, of Maldon, who described having found dark-blue clayey bands in the centre of a quartz reef, some 10 ft. thick, at a depth of about 70 ft. from the surface. The colour in this case, as in that reported by Aplin, disappeared when exposed to air and light, and gold became visible. It is to be regretted that no chemical examination was made, as there was undoubtedly a compound of gold present.

"Be this as it may, there can be no doubt that nearly all the native sulphides contain gold, especially those which also contain silver. I have found it with this metal in every sample of iron-, copper- and arsenical pyrites, galena, sulphide of antimony and zinc-blende, which I have examined from the rocks of this colony; and Dr. Percy proved its existence in every sample of galena he examined, even though they contained little or no silver.

"Bischoff, in reviewing facts like these, says that it has been repeatedly proved that in the decomposition of ore lodes, the silver takes part in the oxidation processes, and is removed in soluble combinations

If such ores are auriferous, and after such a decomposition the lodes undergo mechanical destruction, the gold will, as it is in a very minute state, be carried off with the results of the decomposition. The argentiferous character of the native gold, and the auriferous character of native silver, show that though one metal passed into a soluble form and the other remained metallic, the separation was not complete.

"In this very minute state, gold may possess properties differing from those which it has when in mass. Iron, for instance, when reduced by hydrogen from the oxide, has such a great affinity for oxygen, that, if dropped through the air at the ordinary temperature, it takes fire, whilst ordinary iron-filings, under similar circumstances, are not affected.

"It is therefore possible that gold, under certain circumstances, may, by the presence of silica in solution, become disposed to combine with oxygen, and then to form with the silica a silicate of gold.

"If further experiments prove that alkaline silicates favour the solubility of silicate of gold, this silica theory will be open to but few objections, and the difficulties to impede our progress in solving this most interesting problem in chemical geology will be greatly diminished, as it will not require the presence of strong chemical agents, which are not to be found either in the rocks or in the meteoric waters percolating through them."

The next to attack the subject of the formation of gold-nuggets in drift was W. Skey, Analyst to the Geological Survey of New Zealand, in a paper read in 1872. He remarks:—

"The first theory broached to account for the presence of these nuggets in drifts was that they had been broken off some rich reef and transported by water bodily to the positions in which they are now found by us. At first sight, this appears very plausible; but there are several considerations which, when allowed to have their due weight, rather tend to shake our belief in its competency to explain the case. These considerations have been discussed pretty freely, so I need not detail them here, but will only state that, briefly put, the chief of them are as follows:—The large size of many of these nuggets as compared with any of the masses of gold yet found in our reefs; their position in the drifts, lying sometimes as they do in the upper layers; and their superior fineness of quality as compared with that of any of the reef-gold found in their vicinity.

"Impressed by these facts, Selwyn proposed another theory for explaining the origin of these nuggets, and one which certainly appears to meet the question upon the particular points just cited (already quoted, p. 759, line 10).

"At the time this idea was broached, nothing systematic or thorough had been undertaken towards investigating this matter as to the probable presence of gold in those meteoric or saline waters referred to, and nothing whatever had been accomplished towards showing any likely means by which gold, depositing from such solutions, would be determined upon itself as a continuous coating, and in such quantity as occasionally to form nuggets of the enormous size we find them in such drifts, nor did Selwyn indeed make any suggestion on this matter; perhaps considering the initiation of such an idea sufficient for his part, he left the support of it to the ingenuity of chemists, to whom in fact such a labour rightfully belonged; in reality, so little was known in support of this theory at the time of its evolution that it seemed in the highest degree chimerical. Since then, however, chemical investigations have given us results greatly in favour of this idea. Thus in the first place, as regards the presence of gold in a soluble state in the waters percolating our drifts, it appears that Daintree found gold in pyrites which had obviously replaced the organic structure of a tree occurring in a drift-bed, and Newbery, Analyst to the Geological Survey of Victoria, afterwards obtained the same results upon other pyrites occurring in a similar manner, both results showing that gold must have been 'presented to the pyrites in a soluble form.'

"Since that time, gold has been by no means unfrequently discovered to be present in certain mineral and mine waters, and indeed Daintree has recently found gold while testing the water of a mine in Victoria.

"Perhaps, though, the most important communication we have relative to this subject is that of E. Sonstadt, 'On the Presence of Gold in Sea-water' (*Chemical News*, 4th October, 1872). This metal has indeed before this been alleged to exist in sea-water, but these allegations have not been sustained with such evidence and accompanied with such detailed description of processes employed as entitled them to an unreserved belief on our part. Sonstadt's experiments, on the other hand, are detailed minutely, and his statements are supported by the results of different processes.

"The amount of gold present in the water taken from Ramsey Bay he states to be very minute, 'less than 1 gr. in the ton,' still the fact of its presence at all in such water is exceedingly interesting as showing an escape of gold from the land seaward, and so confirms the correctness of the various allegations I have referred to respecting the auriferous character of certain of our springs and mine-waters.

"Thus in different ways, the first question involved in Selwyn's theory is answered in a most satisfactory manner.

"As to the means by which the gold present in these waters has been reduced therefrom and aggregated in masses, solid, homogeneous, and occasionally of considerable size, we have no lack of substances certain to be present in these drifts, and capable of effecting the reduction of gol' and silver from the kind of solutions likely to be present there. In various kinds of organic matter and in sulphate of iron, we have substances which will effect this with facility; but we have no sure evidence as yet to show that either of these substances will aggregate the gold which they reduce, or locate it in a marked manner, or preferentially, upon the gold already reduced.

"That gold will be reduced by these substances is certain, but all our present experience in regard to the deposition of gold by them shows that gold so reduced will be dispersed rather than aggregated, so that it would appear that nuggets of gold could not well be formed in this manner.

"In our mineral sulphurets, however, we have agents which are not only capable of reducing gold and silver from solution, but besides are capable of locating them when so reduced in coherent and bulky masses.

"I may state that their nuclear action upon gold depositing from solution by aid of organic matter was suggested by Wilkinson, while their competency to reduce the gold from solution without addition of organic matter was shown by me; thus the aggregation of the nuggety forms of gold from solution becomes a still more simple matter, only one reagent being necessary, so that there is a greater probability of such depositions obtaining than were a double process necessary.

"Knowing the action of sulphides, the manner or the mode of formation of a portion at least of these nuggets seems apparent. Conceive a stream or river fed by springs rising in a country intersected by auriferous reefs, and consequently in this case carrying gold in solution; the drift of such a country must be to a greater or lesser extent pyritous, so that the débris forming the beds of these streams or rivers will certainly contain nodules of such matters disseminated, or even topping them in actual contact with the flow of water.

"It follows then from what has been previously affirmed, that there will be a reduction of gold by these nodules, and that the metal thus reduced will be firmly attached to them, at first in minute spangles isolated from each other, but afterwards accumulating and connecting in a gradual manner at that point of the pyritous mass most subject to the current, until a continuous film of some size appears; this being formed, the pyrites and gold are to a certain extent polarized, the film or irregular but connected mass of gold forming the negative, and the pyrites the positive end of a voltaic pair; and so according as the polarization is advanced to completion, the further deposition of gold is changed in its manner from an indiscriminate to an orderly and selective deposition concentrated upon the negative or gold plate.

"The deposition of gold being thus controlled, its loss by dispersion or from the crumbling away of the sustaining pyrites is nearly or quite prevented—a conservative effect, which we could scarcely expect to obtain if organic matter were the reducing agent.

"Meanwhile there is a gradual wasting away of the pyrites or positive pole, its sulphur being oxidized to sulphuric acid, and its iron to sesquioxide of iron or hematite, a substance very generally associated with gold-nuggets. According to the original size of the pyritous mass, the protection it receives from the action of oxidizing substances other than gold, the strength of the gold-solution, length of exposure to it, and rate of supply (velocity of stream), will be the size of the gold-nugget.

"As to the size of a pyritous mass necessary to produce in this manner a large nugget, it is by no means considerable. A mass of common pyrites (bisulphide of iron) weighing only about 12 lb. is competent for the construction of the famous 'Welcome nugget,' an Australian find, having weight equal to 152 lb. avoirdupois.

"Such masses of pyrites are by no means uncommon in our drifts or the beds of our mountain streams. The general velocity of the current flowing over such pyritous matters would in all probability be such as would prevent the development of any crystalline form in the gold thus deposited, as we know very well that for such development motion is unfavourable. The form most likely to be assumed by these deposits then would be the mammillary, precisely that in which our nuggets as a rule occur.

"Upon this mode of accounting for the presence of large nuggets in our drifts, their occasional great superiority in point of size to any auriferous mass as yet found in our reefs, and their superior fineness to such reef-gold, admits of easy explanation.

"Firstly, as regards their comparative size, if we only admit that reef-gold is also deposited by pyrites, and if we assume that the strength of the gold-solutions forming these varieties of gold respectively was not greatly different, it is only reasonable to suppose that the gold-masses formed in this manner in drift would attain the greatest dimensions, for in the first place this gold in depositing would certainly aggregate more, as the pyrites in the drifts or river-beds would be less continuous and more sparsely distributed than that in reefs.

"Further, the supply of gold to pyrites lying in these drifts or river-beds (and so exposed to rapidly changing waters) would be far more copious than to pyrites cooped up in a rocky fissure, and so in contact only with water stagnant or nearly so.

"And, secondly, as regards the generally superior quality of these nuggets to gold found in the reefs, it will, I think, appear from the following considerations that such a difference in favour of drift-gold is to be expected.

"I have previously shown that silver is deposited with greatest rapidity and certainty upon pyrites from solutions which are alkaline from presence of the fixed alkalies or alkaline earths, and that as such solutions are passed from this condition to an acid one, the silver present in them is retained in solution; any gold, however, that may be mixed with such silver is deposited upon this reducing agent, no matter which of these conditions the solvent is in.

solvent

"Now this alkaline condition is precisely that in which, as far as we can ascertain, our lodes or rocks must have been at the time of the deposition of the gold and silver now found in them, and this alkalinity would especially manifest itself in those reefs which traverse rocks of a basic nature, such as diorites or serpentines: hence, by the way, the large proportion of silver alloying the gold found in these reefs, as compared with that alloying the gold found in the lodes of our schists or older formations.

"But though the waters percolating our reefs must be to a more or less extent of an alkaline nature, the drainage waters issuing from them will lose a portion of this alkalinity as they are exposed to the air, or to the products of decomposing organic matters, from having absorbed a quantity of carbonic or other acids (sulphuric, humic, &c.), thus in some measure, according to the distance such waters have travelled from their springs, will their condition be changed until their alkalinity may give way to neutrality, or even acidity, either of which conditions is, as I have stated, unfavourable to the liberal deposition of silver along with gold from such waters. Hence it is apparent that from the instant the waters percolating rocks or lodes leave them to form springs, &c., they are continually passing from a favourable condition to one eminently unfavourable for the deposition upon pyrites of what silver they may contain. Consequently the deposition of gold from solution being as we know unaffected, or but slightly so (comparatively), by the condition of the solvent, the great purity of gold deposited from these surface waters is explained.

"The above explanation of the greater purity of our alluvial or drift gold over gold found in the reef is, I think, much more plausible than that which attributes this difference to the interaction of solutions of gold upon the auriferous masses transported from the reef, whereby the silver of these masses is replaced by gold and so removed, leaving the mass correspondingly richer in gold. That this process can be continued until our largest auriferous masses can be thus affected throughout appears to me impossible when we consider the imperviousness of such metallic masses to liquids, and how nearly the atomic volumes of gold and silver approximate. That a superficial change, however, in this direction may occur is by no means improbable, but such would escape detection unless it were especially sought for. Thus the hypothesis advanced by Selwyn as to the manner in which the nuggets of our drifts may have been formed receives support upon all those points which appear of any importance.

"That nuggets of some size may, however, be in a few instances transported bodily from these matrices into the drifts or water-courses is by no means improbable, but in this case they would, I think, partake of the usual quality of the reef-gold of the country about, and so would be inferior in this respect to gold formed in the manner above described.

"Whatever may be the origin, however, of any particular nugget, or of nuggets generally, when we consider the auriferous nature of many mine-waters, also that of sea-water, together with the decomposing and aggregating action of metallic sulphurets upon the gold of these waters, we cannot avoid the conclusion that gold is now being deposited and aggregated in many of our drifts, and that such depositions have been going on from remotest times.

"In conclusion, the questions as to the source of the gold of our nuggets, the nature of the agencies by which it is dissolved, and the precise chemical state in which it exists in our auriferous waters, are subjects which it is not incumbent upon me to discuss here. I will, however, take leave to make a few observations upon them now.

"As regards their source I think this is rather in gold as disseminated in certain of our slates, sandstone, or schist rocks, than in that of our reefs.

"In reference to the nature of the solvent, I have shown that sulphuretted hydrogen attacks gold at ordinary temperatures, forming a sulphide of the metal, and we know that all the sulphides of this metal we have to this time formed are soluble in alkaline sulphides; therefore, as both these agents are generally present in waters situated at some depth in our rocks, we may very reasonably suppose that a portion, if not all, of our gold has been brought into solution by these agents.

"The state to which such auriferous solutions might pass when exposed to air and carbonic acid is not easy to determine, but of this we may be certain, that it could not well be one unfavourable to the exercise of the reducing properties of metallic sulphurets upon the gold compound present in them."

In more recent laboratory reports, Cosmo Newbery returns to the subject of the deposition of the gold in veins. He says:—

"The main practical interest in this subject is the attempt to discover some of the natural laws by which the deposits of gold and auriferous minerals in the quartz lodes and auriferous strata have been governed, and by so doing to aid the mining interests of the country. Most geological observers are agreed that our auriferous deposits are of aqueous origin; in fact that is the only way of reconciling the various phenomena.

And observations have proved that gold is deposited in and with recent mineral formations. The first question is—What sort of a solution is necessary to carry the gold and associated minerals, and have we in the natural waters of the mines this necessary solvent? This fluid must have the power of holding a number of minerals in solution at the same time, in such a manner that they may be all deposited together, or at any rate holding certain elements or compounds which, by reacting on minerals already deposited, will produce the minerals as we find them.

"H. Müller, in his description of the ore deposits of Freiberg, notes that the deposits of ore vary with the rock through which the lode passes, and Von Cotta has adopted the term 'ore-carriers' for those rocks exerting a favourable influence on the deposit of ores. He remarks that, although the lodes are not always rich while passing through the rocks conducive to the deposit of ore, and indeed are very frequently barren, still when the lodes do contain ore it is only when in these rocks. This all points to these rocks either supplying the waters with their mineral contents, or exerting some influence to make them deposit what they held.

"Ulrich has on several occasions drawn attention to the necessity for the study of the rocks through which the quartz reefs pass, and the probability of the 'shoots' of gold being in some way connected with the nature of the wall-rock of the vein where the shoot occurs. He says that, although Victorian reefs on casual observation appear to be layers running with the strike and in the bedding of the Silurian rocks, closer examination shows that this is not the case—they are a variety of layer lodes. The greater number certainly lie within the line of strike, but underlie at varying angles through the bedding of the rock, a feature which results in the 'reef' passing more or less gradually from one bed to another. The greater the angle of difference, and the more regular the dip of the reef in strike, the quicker this passage will be. The points to be ascertained are—Do one or more particular beds of rock enclose the shoots of gold? and if so, does the rock in any way differ from that enclosing the barren parts of the reef? The physical character of the rock, as well as its mineral composition, may play an important part. Ulrich mentions that the richness of the reefs in the Upper Silurian rocks is often increased when they pass into or are in the vicinity of a certain class of rocks which have a mineral composition differing from the ordinary shales, &c.; while in the Lower Silurian, the differences in the rock are apparently only physical. In some instances, it is found that, where the rock becomes soft, the quartz reef widens, and is richer in gold than where the rock is hard and the reef narrow. This is reversed in quite as many, if not more cases, the reef being poor where it is wide in soft rock, and rich where it is narrow in hard rock. When the latter occurs, it is usually assumed that a simple concentration has taken place; but there are so many instances of the richness increasing with the width of the reef that some other reason must be sought for.

"Where the mineral components of the rock change, as with the occurrence of dykes and masses of intrusive rock in the Upper Silurian of Wood's Point, Crossover Creek, Walhalla, Alexandra, &c., a notable increase in the richness occurs in the quartz as it passes from the slates towards or into the dyke. By the examination of carefully prepared microscopic sections, Ulrich shows that these rocks having a good influence are of one special variety—they are hornblendic, true diorites; while all the rock masses and dykes, which are augitic diabase, have hitherto been proved to be non-auriferous. Until Ulrich's observations, all these rocks were classed and mapped as diorites. It is very difficult to distinguish one from the other except in microscopic sections. So far as the examination has gone, this rule of the diorite favourably influencing quartz veins, and diabase having no such influence, holds good not only for Victoria, but also for Tasmania and Queensland.

"Where decomposition or changes of character, either chemical or physical, have been caused by aqueous action, there is a difficulty in separating those which may have taken place at the period of the formation of the quartz veins from those of more recent date. In some instances the actions in the past may have differed materially from recent actions; but all the evidence we have must incline us to the belief that in the majority of cases the actions were similar."

Again—

"Some auriferous specimens examined lately have afforded further evidence as to the probable deposition, at very recent periods, of at any rate part of the gold of the alluvial and quartz mines, and of a deposition now going on in many mines.

"Considerable difficulty is experienced in conducting the experiments on this subject, as extreme care is requisite to exclude all possible chance of the presence of finely-divided gold which has been held in suspension in mine-water, either by itself or with pyrites, quartz, and earthy matter. A sample of mud deposited from the water of a mine on the Hustler's line of reef, Sandhurst, was examined by careful washing, and it was found that the heavier portion consisted of auriferous pyrites and free gold. The particles of the latter were of sufficient size to be recognized by means of the microscope. They were irregular grains apparently flattened, having been in all probability reduced to their present condition by the wear and tear of mining operations, or perhaps in part derived from the clayey casings of the quartz lode. This mud was not pumped out of the mine with the water, but had been deposited in the workings. Other instances of auriferous mud carried many miles by running water are not wanting. Samples collected from the silt in the creek, several miles below Clunes, gave an appreciable amount of gold to an ordinary assay of 1000 gr., and were also found to contain iron-pyrites. These and other similar determinations have made it necessary to discard a certain portion of the evidence which had been collected to prove that the mine-waters of the present day carry gold in solution, and deposit it whenever the circumstances are favourable, either in the quartz veins or alluvial drifts.

"The following determinations (qualitative) have been made:—1st—Incrustations from steam-boilers using mine-water at Maryborough. The residue, after removal of all soluble matter, showed no gold with the microscope, and but few grains of silica. It was a fine powder of grey-brown colour. Fused with pure litharge and assayed, it gave an easily recognizable button of gold. The incrustation consisted of chloride of sodium, sulphate of magnesia, and sulphate of lime. 2nd—Mine timbers collected from the following mines:—

No. 1—Spanhake Company, Ballarat
No. 2—Black Hill ,, ,,
No. 3—Gravel Pits, ,,
No. 4—Energetic ,, Sandhurst
No. 5—Koch's Pioneer, ,,
No. 6—Great Extended Hustler's, ,,
No. 7—, No. 8— } Hustler's Reef, Sandhurst
No. 9—Thanet Mine, ,,
No. 10—Koch's Pioneer, ,,
No. 11—Bute Mine, Scarsdale.
No. 12—Reliance, ,,
No. 13—Ellesmere claim, Scarsdale.

"The samples of timber were for the most part quite sound; one or two were slightly decomposed for somewhat less than an inch from the surface. Though the whole of them were traversed in all directions by cracks, only to be detected by thoroughly drying them, these cracks were in all instances found to contain ferruginous clayey matter, and in several cases iron-pyrites. The soundest samples were taken and burnt in a clean new muffle, first having split the timber into small pieces, and cut away as carefully as possible all the outer portion, the clayey cracks referred to, and any parts that were soft or decayed, which might have taken up by absorption any auriferous mud while the timbers were in the mine. The ash obtained was of a red colour, owing to the presence of oxide of iron. It was washed with water and weak hydrochloric acid, and then examined microscopically. No gold was detected, but it might have been easily hidden by the earthy insoluble matter of the ash. The whole was then fused with a weighed quantity of pure litharge, and cupelled, and gold was detected readily. The button was dissolved, and confirmatory reactions obtained from the solution.

"These experiments were repeated with similar results. In the residues examined by the microscope, were seen a number of angular grains of silica, and as these rendered it possible that some crack or fissure which had absorbed muddy water had been overlooked, some thin chips were cut from the wood where it was perfectly solid; these were burnt, and a similar red ash with the grains of silica was obtained.

"Another quantity of chips was boiled in water, and yielded sulphates and chlorides of the alkalies and magnesia; these were completely removed by successive waters, and the wood oxidized, so as to form sulphuric acid from any pyrites that might be present. This acid and iron were then detected in the solution. These tests prove that gold has found its way into the dense unchanged wood of the mine timbers, and that it must have got there in solution; for it is impossible to suppose that grains of gold and pyrites can have been drawn into the wood by capillary action. The grains of quartz were angular and transparent; and I can only explain their presence as has been done in the case of other wood in which they are found, and which has not been in mines, by supposing them to have been enclosed during the growth of the tree.

"By discarding all the soft portions of the wood and the cracks from these tests, I have omitted all the parts where chemical action would be most active and the best results obtained: 8 lb. of specimen No. 10 gave 0·002 gr. of parted gold: an average of specimen No. 13, weighing 8¾ lb., 0·002 gr. of pure gold: 4 lb. of the external soft wood gave 0·01 gr. of gold. This shows a much larger amount of gold than the internal portions; and as the pyrites obtained is crystalline (not loose broken fragments), showing a surface resembling what is termed 'secondary' pyrites, and is firmly fixed on and in the woody matter, I believe it is due to chemical deposition, and not accidentally absorbed.

"I cannot at present say whether the gold is in the pyrites or as free gold; but as I have been unable to detect any microscopically, I think it is with the pyrites.

"Attempts have been made to determine the actual presence of gold in mine-water by depositing it on plates of copper connected with a galvanic apparatus; but, though gold was found in the crust which coated the plates, the trial could not be relied on, as no test had been made of the copper before the experiment was begun. These experiments will be repeated, with a specially devised apparatus, so that not only shall the copper be pure, but the flow of water made to pass through a filter in order to remove any suspended matter.

"It is also proposed to make some trials similar to those by which Sonstadt proved the presence of gold in sea-water. The evidence of its presence and the continued deposition may be classified under the following heads:—

"1. Gold found with pyrites in the wood of the deep leads, and in the charcoal enclosed in the lower parts of the basalt flow covering the leads, first noted, I believe, by R. Daintree.

"2. Gold found in the trunks of trees converted into pyrites in the same leads, and in the pyrites cementing together the quartz pebbles of the drift, as well as the pyrites forming stalactitic masses on the lower side of the basalt over the lead.

"3. The incrustations from steam-boilers fed with mine-water.

"4. The gold found in mine-water by Daintree.

"5. Gold and pyrites in mine timber.

"6. Gold in the secondary pyrites coating the joints and filling fissures in the quartz of the lodes.

"Some persons who have reviewed the experiments made by Daintree and Wilkinson, have been inclined to doubt the part played by organic matter; and William Skey, of the Geological Survey of New Zealand, states that the action of organic matter in the solutions of gold is simply to cause a general reduction and distribution of the gold, causing it to deposit on the bottom of the vessel as a powder, but not in any way aiding in the formation of nuggets or crystals. I have tried many experiments with organic matter in solution of gold, and though some have been as he describes, many have been otherwise; and I still believe that organic matter has played an important part. In examining the organic matter which I have had in the solutions, I find that it becomes impregnated with gold, so much so that when cut it has a metallic lustre, and may be burnished, and yet little gold was deposited as a crust on the vessel or as a powder. In solutions where no nucleus was placed for the gold to deposit on, films were formed, which floated on the surface, gradually increased in size and thickness, and then sank; on examining these, they were found to be masses of small crystals. Unfortunately, I did not see Skey's interesting papers till long after they were published, and have only lately returned to these experiments. The crystalline gold has been replaced in the solutions with and without organic matter. Gold plates, having had the surface roughened by the action of acid, have also been placed in similar solutions of chloride of gold, and the results will be duly recorded.

"Like Skey, I have not found that hammered discs of gold increase in size, but I have little doubt of the others with a rough or natural surface doing so. Daintree's discovery, upon which all these experiments have been based, the observation of which Skey somewhat severely criticises, was not made with a hammered disc of gold, but with a rough fragment. Ulrich, who was present when Daintree discovered the enlarged piece of gold, related the circumstances to me thus. The gold originally placed in the bottle was a small fragment which had remained undissolved after making some chloride, and the bottle was closed with a cork; when again observed, the solution was colourless, and the fragment of gold of such a size that it could not be removed from the bottle, through the narrow neck. Finding that a part of the cork was floating in the bottle, it was suggested that the organic matter had caused the gold to deposit, and that the organic matter of the auriferous leads might play an important part in the formation of nuggets. Wilkinson then successfully repeated the experiment.

"Upon examining numerous samples of auriferous Tertiary or recent pyrites, I find that the gold is distributed throughout the mass, and that there is really no more evidence of the pyrites having acted as a nucleus for the gold than there is for the reverse, i. e. the gold for the pyrites. Further, we have, so far as I know, no evidence in nature of gold coating pyrites; it occurs in pyrites, or attached to pyrites. In fact they are found imbedded in each other, but with no further relation than that they were deposited together. Now we know that, under ordinary circumstances and from laboratory solutions, gold is deposited on pyrites, and, as Skey has pointed out, the pyrites proportionately decomposed; there must have been other conditions and affinities which prevented our laboratory reactions taking place, for we do not find gilded pyrites. Brown iron-ore, quartz, and iron-pyrites have been found separately in the centre of gold-crystals; may not all these minerals have acted simply as inert nuclei? Skeleton crystals of gold in the form of the rhombic dodecahedron have also been observed over the pentagonal dodecahedron of pyrites, showing that the process here involved is actual crystallization, and not plating or coating, which would have merely covered the faces of the pentagonal dodecahedron."

Prof. Whitney (1880) states it as his confirmed opinion, after many years of careful examination of important mining regions in various countries, that the occurrence of metalliferous ores is rather a surface phenomenon than a deep-seated one. "The conditions favourable to the formation of veins and vein-like or segregated masses are more likely to have existed near the surface than deep down below it. Such conditions would be—in part at least—diminution of temperature, relief from pressure, and, in the case of true veins, the existence of fissures. The history of mining operations shows beyond dispute that bodies of ore occurring in the segregated form are, on the whole, not to be depended on for persistence. And even true fissure-veins must eventually give out in depth, if for no other reason than the change in the character of the enclosing rock brought about by intense heat. Neither would fissures be likely to continue to exist, nor the materials filling them to retain a distinct form, where the temperature was above the melting-point. Thus, whatever theories we may adopt for the formation of mineral veins, we are led to the conclusion that they must, as a general rule, be better developed near the surface than at great depths. The fact that in some important mining regions the very upper portion of the veins has been oxidized, and then dissolved away by water, is very easy of comprehension, and not in conflict with what has been stated above.

"The fact is not to be ignored that the two by far most important and productive gold-mining districts of the world are regions of former intense volcanic activity. Australia and California exhibit the same phenomenon of rich auriferous detritus buried beneath masses of lava. Although the eruptive rocks, in these cases, are not the direct repositories of the precious metal, there would seem to be strong reasons for believing that there is a genetic connection between the volcanic activity and the enrichment of the adjacent strata.

"The ranges of the Andes and of the North American Cordilleras certainly surpass all other regions in the world in metallic wealth; for hundreds of years they have been supplying the world with a large part of its silver, and no inconsiderable proportion of its gold. The richness of the Peruvian mines long since became proverbial, and the word 'bonanza' is now familiar to all from its association with the mines on the Comstock lode and others of the Far West. These regions have been the seat of the most intense volcanic activity during Tertiary times, and in all probability in previous geological epochs. It is hardly possible therefore, in view of all the facts, not to admit that there is likely to be some genetic connection between the manifestations of igneous forces and the impregnation of the rocks with the precious metals and metalliferous ores.

"Quite a number of theories relating to the geological epochs at which the various metals have made their appearance, or been introduced into the formations where we now find them, have been put forth by chemists and geologists. Gold has been specially favoured in this respect. No theoretical views regarding this metal have been so widely promulgated and generally accepted as those of Murchison. According to this eminent authority, gold in paying quantities is exclusively confined to the Palæozoic rocks, into which, however, it was introduced at a very late geological epoch. It was also a favourite dictum of this geologist that auriferous quartz veins are a superficial phenomenon, and that mines of this metal would not hold in depth as persistently as those of other metals. The discoveries of the California Survey in regard to the age of the gold-bearing formations of that State have entirely refuted the (until 1864) generally accepted theory of the exclusively Palæozoic age of rocks of this kind, although this fact was not admitted by Murchison in his latest publications.

"The great depth to which some gold-mines have been wrought, with profit, both in California and Australia, in connection with many other facts observed in various parts of the world, justifies us in asserting that auriferous quartz veins are as persistent, on the average, as those worked for the other metals. That the impregnation of the rock with gold took place at a comparatively recent geological epoch, at least in certain prominent and important mining regions, cannot be denied. These are regions of former intense volcanic activity, and the period to which that belongs is unquestionably Tertiary. In regard to mining districts where gold and other metals and metalliferous ores have been found in considerable quantity, and where there have been no striking manifestations of volcanism, accompanied by ejections of lava, as, for instance, along the greater portion of the Appalachian Chain, and especially on its eastern border, no definite statement can be made in regard to the geological period of the metalliferous impregnation. It would appear, however, that the evidence is, on the whole, in favour of this having taken place at the time of, or shortly after, the upheaval of the ranges themselves. To prove that the rocks of such ranges as the Appalachian and Scandinavian, which are surrounded by entirely unaltered Cretaceous and Tertiary strata, have been the scene of extensive chemical reactions during those later periods, would be a difficult task. Under any circumstances, there is no basis for Murchison's idea that gold was—to use his own words—'the last formed of the metals'; for the impregnation of the quartz veins, or rather its segregation, at the same time with the quartz, into veins or vein-like masses, was merely a collecting together of particles previously existing in the rock, and not by any means a new creation of them.

"It does appear as if there was some truth in the idea that the finding of large pieces of gold in the gravel is not justified by what we see of the occurrence of the metal in the quartz. It is certain, at all events, that the form of the ordinary nugget is something different from that which is offered by the gold as originally deposited.

"The larger part of the gold contained in the quartz exists in the form of particles invisible to the naked eye; and there are many mines which are producing largely and paying handsomely, where free gold can hardly ever be seen at all in the rock going to the stamps. Indeed, there is a general belief among the miners that, 'specimen mines'—or those where the free gold is segregated from the quartz so as to form handsome specimens—are not likely to be persistent.

"Where the gold is visible to the eye in the quartz, the predominating form which it exhibits is that which is best expressed by the term 'scaly,'—a word used by the placer and hydraulic miners in describing the small, rounded, flattened pieces with which they so frequently meet.

"It seems to be the fact that the gold in the quartz never has the proper 'nuggety' character. The metal does not occur as deposited from solution, in solid, smooth, and rounded masses, but in scaly, foliated, filamentary, arborescent, or crystalline forms. The question arises, then, how has this change been brought about? And connected with this is the inquiry whether there is really ground for believing that pieces of gold, after being separated from their original matrix, do increase in size, either by chemical or mechanical causes.

"The finding of large nuggets in the hydraulic mines of California seems, so far as ascertained by the investigations of the Geological Survey, to be of very rare occurrence. There have been, however, occasional statements, in books and newspapers, of such lucky finds in the ordinary placer mines. Most of these, of course, took place many years ago. The largest nugget of which the writer has ever heard is one said to have been found at Vallecito, in 1852, which weighed 25 lb. It is stated by W. Birkmyre, in his list of great nuggets found in various parts of the world, that there is in the collection of the Bank of England a nugget found in Carson Creek, in 1850, and weighing 18 lb. 3 oz. The above-mentioned find at Vallecito is given on the same authority. Nothing is known of its form or of the character of its surface. Such finds seem to be much more common in Australia than they ever were in California, judging from the lists which have been given in the official publications of the Geological Survey of Victoria.

"Large masses of gold have occasionally been found in the quartz and in the bed-rock in California. The occurrence of such at Spanish Dry Diggings has been mentioned. Carson Hill is another locality from which similar facts have been reported. As far as the results of his own investigations in California are concerned, the writer is not able to find sufficient evidence to support the opinion that the large size of the nuggets in the gravel presents difficulties requiring the aid of chemistry for their solution. If it be true, as the writer believes, that quartz veins as well as all others, as a general rule, have been richer near the surface than they are at great depths, then the occasional finding of large nuggets in the gravel would not be a matter of surprise. Heavy masses of gold are found, even now, in some of the quartz veins, and somewhat heavier ones may have existed nearer the surface.

"With regard to the manner in which the gold in the quartz loses its characteristic forms, so as to become transformed into the smooth rounded masses occasionally found in the placer mines, there seems to be no theoretical difficulty. In the first place, however, it may be stated that by no means all the nuggets have this character. Many of them exhibit more of their original character than would be expected to be found remaining after ages of pounding between the boulders of the gravel. This is particularly true of specimens collected by Professor Pettee from the hydraulic mines during his last year's investigations, and which have been carefully examined by Wadsworth and the present writer. The same fact has also been stated by Ulrich—who appears to be a close observer—in regard to the Australian nuggets.

"There seems to be no doubt that a 'scraggy'—to use a common miner's term—piece of gold can be transformed into a rounded smooth nugget by a sufficient amount of the right kind of rubbing and hammering, which must have taken place as these great piles of detritus were being shifted from place to place by currents of water. Some of the specimens collected exhibit in the most interesting and convincing manner the transitional form between the rough crystalline form and the smooth rounded one. One in particular, from an unknown locality, purchased by the writer in a shop at San Francisco, has one side almost perfectly smooth, and rounded edges turned over upon the back, which itself is covered with crystalline branchings, still retaining a large part of their original delicacy. It is evident, in this case, that the specimen has been protected on one side, while the other has been subjected to abrasion and pounding, the result being a nugget presenting at the same time and in most remarkable perfection, the characteristic forms of quartz-gold and placer-gold.

"That the masses of gold, when they have been released from the quartz veins and have begun to be rolled about in the gravel, could by any possibility be so situated as to become subjected to any chemical influences by which their mass could be enlarged, seems—to the writer, at least—highly improbable. That occasionally pieces of the metal may be united by pressure or by hammering between the gravel boulders, and that thus a larger mass may be formed by the union of two or more smaller ones, through purely mechanical agencies, seems not impossible; and some observations of Wadsworth appear to corroborate this view."

In 1881, Prof. T. Egleston, of the New York School of Mines, published his views of the formation of gold nuggets and placer deposits. His paper may be summarized thus:—

"The origin of gold both in placer deposits and in veins, and especially the origin of nuggets, has been the subject of repeated discussions and investigations. In 1874, I made some examinations of the hydraulic mines of California, and was very much struck with the distribution of the gold throughout these deep placers, which were almost invariably poor on the surface, while gradually growing richer towards the bed-rock. The constant presence of fossil wood, and the large quantity of organic matter contained even low down in these beds, was also remarkable. Not being satisfied with the various theories advanced to account for the formation of these deposits, I began an investigation early in 1879 on the conditions of solubility of gold and the causes of the loss in working gold-ore in a large way. The researches which I have undertaken show that gold must be considered a soluble "rather than an insoluble metal, and that the conditions of solution are "such as will be found anywhere where gold is likely to occur, and the "solution may take place even under the ordinary circumstances of surface "drainage, and may be going on freely even where the presence of gold "has never been suspected, and that there are causes enough in nature to "produce the solution of the gold in sufficient quantities to account for all "the phenomena of both the vein and placer formations.

"The general theory with regard to the formation of these placer deposits and nuggets has been that they were the result of the destruction of pre-existing vein-matter, which does not accord with the facts as shown in the deep placer deposits. The gold in such case would be distributed in layers of unequal richness throughout the bed, the richness depending on the amount of deposition taking place at any one time, and would not occur in increasing richness from the top to the bottom. Further, every particle of gold of whatever size would have a rounded form, resulting from its abrasion against the harder rocks, which is not the case, the small as well as the large grains being of very irregular shape. It must also be borne in mind that most of the veins from which the gold is supposed to have come had a gangue of quartz. The gold is much softer than the rock; the quantity of precious metal contained in the vein would also be very much less than the rock, so that in the destruction of the formations there would be a very small amount of gold being abraded and ground in a very large quantity of rock. It is therefore likely that the coarse particles of gold, which is so much softer, would be comminuted at least as fine as the rock, and the smaller ones much finer than the rock, so that the difference in density would hardly tend to make a concentration by any subsequent action of wind or water, since the small particles of gold would tend to float away and thus prevent the concentration. Where the large particles are not in sufficient quantity to make an extended natural concentration possible, and where the deposition of the sediment of the rivers is taking place, the result would be a very small quantity of almost impalpably fine gold distributed uniformly in a very large amount of comminuted rock, or a production of clays resembling that used to make brick around Philadelphia, which contains very small amounts of gold uniformly distributed through it (see p. 181). The structure, too, of each one of these particles would be the same as that of the rock with which it was abraded, and would be uniform. It is, however, well known that the grains of gold found in the placers are not uniform; some of them are flattened with rounded edges, others rounded, and most are mammillary, all of which forms are not probable, and hardly possible, under the conditions suggested. A nugget rounded like a water-worn pebble is a great exception in any of the placer deposits.

"While the theory of vein destruction might in some cases account for the presence of gold in small quantities throughout the sands in grains large enough to admit of concentration, it could never account for the presence of large nuggets, which if they had been transported any distance by water would have lost their mammillary form. Admitting the greater size and force of the ancient rivers, it is impossible to conceive that such large and irregularly shaped nuggets as those from Australia, Siberia, and from this country could ever have been so transported by water as to be entirely relieved of all their gangue, without having themselves assumed much more regular surfaces and a more uniformly cobble-stone shape. On the other hand, slow accumulations from solutions of varying strength and a deposition of unequal rapidity continued for a great length of time, accounts perfectly both for the form and for all the attendant phenomena. It is a fact, moreover, that very large masses such as these nuggets have never been found in veins, and are confined exclusively to placer deposits. The detrital theory accounts still less for the fact that in many of the deposits, especially where the bed-rock is soft and porous, the gold often enters it to the depth of nearly a foot, and it is frequently the richest part of the deposit.

"In 1867, Wilkinson (see p. 759), of Australia, made a series of researches with reference to the effect of organic material on the deposition of gold. Sonstadt (p. 769) also made a series of researches on the presence of gold in sea-water, and found it to be present in the ratio of about 1 gr. to the ton of water, or about $1 (4*s.* 2*d.*) for every 25 tons of water.

"Up to this time, gold had always been considered as a very insoluble substance, because it was insoluble or very nearly so in most mineral acids. Ingenious metallurgical processes based on this insolubility have been invented, and are still in constant use; but it does not follow that because gold is not affected by the ordinary acids it is therefore not soluble in other substances much more likely to be found in nature. The action of organic acids and of the alkalies were left out of view, and also the fact that the solution of infinitesimal quantities may acquire great significance in a geological sense.

"Bischoff (p. 763) found that sulphide of gold is slightly soluble in meteoric waters, and much more soluble in a saturated solution of sulphuretted hydrogen in water. It has also been ascertained that chloride of gold in minute quantity in an alcoholic solution may remain in solution in the presence of proto-salts of iron, and that metallic gold is slightly soluble in solutions of the per-salts of iron. But the theories founded on these discoveries supposed that gold was much less soluble than it really is, and that the solution required peculiar agencies and a set of circumstances not likely to occur everywhere. Its diffusion in sea-water was accounted for by the presence of chlorine, iodine, bromine, and of alkalies, and these conditions were not thought to be of general application in the explanation of the phenomena exhibited in mineral veins.

"Selwyn, the government geologist of Victoria, proposed a theory of solution (already described on p. 762).

"These researches and theories, however, did not attract very much attention, and the old theory of the destruction of pre-existing veins was still adhered to. It is to be observed, however, that when gold does come from the destruction of veins, the surfaces are rounded and worn smooth, as is shown in the larger boulder of quartz containing gold detached from a vein in Venezuela, which is now in the collection of the School of Mines. This is in entire contradiction to the mammillary structure of the nuggets. If they had been transported far by water, they would have been rounded and water-worn to much more regular surfaces. These worn surfaces would of course have been confined entirely to the outside of the nuggets, any cavities existing in the interior of the piece would have been in the condition in which they left the vein, and the edges of any crystals found there would have been sharp; while in the nuggets, the mammillary form exists even in the cavities of the interior, and even where crystals or the commencement of crystallization is observed, the edges of the crystal are very often blunted or rounded, showing both deposition and solution on these edges.

"It is also to be noticed that the analyses of nearly all the samples of gold taken from veins show it to be much less pure than the nuggets found in the placer mines of the same district. If the gold of the placers had come from eroded rocks, it would be of the same composition as that of the veins of the district in which it was found. It is well known that most of the gold nuggets are pure, while the gold of the veins is of a much lower grade, containing considerable quantities of silver and other foreign metals. Thus the Ballarat nuggets are 992·5 fine, the Australian nuggets vary from 960 to 966; those from veins in California from 875 to 885; in Transylvania, 600 with 399 of silver; and in Nevada there are some of 554 of gold and 429 of silver, and others only 333 of gold with 666 of silver.

"It must be remembered also that the violence of the old placer currents was very much greater than that of the ordinary streams of these days. The rivers were not only larger and deeper, but more rapid, and the results of their action would have been an almost complete comminution of the gold by its rubbing against the harder rocks. If this were the whole of the process, and no further action had taken place, the gold would be found in the sands in this comminuted condition exclusively, and few if any of the particles would have escaped the battering and pounding process incident to long exposure to rolling rocks, and the deposits resulting from it would be found on the bed of the stream.

"Gold is, however, also found as nuggets, and in small particles in rocks which have never been disturbed from their original positions, but which have been decomposed to a considerable depth, and it then has the same rounded form, occupying positions which make it evident that it must have been formed *in situ*, and never have undergone any abrasive action. The nugget found in 1828, in Cabarrus County, N.C., which weighed 37 lb., and the one found in the valley of Taschku Targanka, near Miask, in Siberia, which weighed 96 lb., were both found under such circumstances in a decomposed dioritic rock. In some few cases, it has been definitely ascertained that the gold has been dissolved and precipitated in the decomposed rocks, for it has penetrated only just so far as the decomposition has allowed it, the yield in gold ceasing entirely at the point where the rock allowed no further filtration; while in other rocks of a more porous nature in the same district, the gold has penetrated to a depth not yet ascertained. Such a condition of things is not uncommon in the gold-belts of the Southern States.

"Admitting that heavier masses of gold did exist in the veins disintegrated by the ancient rivers, gravity alone cannot account for the bottom deposits (which are often 300 ft. from the surface) being the richest. It would have required greater agitation of the earth than we have any evidence for believing ever took place to sift the coarse particles even through 50 ft. depth of earth, and there is no indication that these deposits after they were once made were ever disturbed. It is undoubtedly true that in shallow placers, where the bed-rock comes near the surface, the surface-soil is rich; but it is the invariable rule that in the deep placers the richest deposits are near the bed-rock, and at a great distance from the surface.

"There is a tradition, which is prevalent in all the gold-mines of the South, and in those of some other districts, to the effect that gold grows, so that every few years the tailings of the old mines are re-worked, generally with a profit; the quantity separated each time, according to the local tradition, being in proportion to the length of time the material has remained undisturbed. As there is no opportunity for the gold in these sands to accumulate by gravity, the people of the region believe that gold grows like a plant.

"It would not, however, be rational to deny a theory so easily explained as the formation of placers by the destruction of vein-matter without having some other to replace it. If the theory of the destruction of pre-existing veins is not tenable, we are bound to examine carefully whether there are causes in nature sufficient to account for solution, and what are the agencies that render the gold soluble. A series of experiments have been made on this subject lasting over many months, both synthetical and analytical, which seem to be of considerable importance in the study of the origin both of placer and vein phenomena. In this investigation, most of the known salts of gold were prepared; but as the chloride is most easily made, this was made the basis of almost all the solutions. While making the chloride of gold for the solutions, some sponge-gold was placed in a tube and heated in a current of chlorine-gas until the chloride of gold formed was entirely sublimed. It deposited at the upper part of the tube directly over the gold, and as the tube cooled, on the gold also in fine transparent crystals ½ in. long. This tube, when cool, was closed while full of chlorine, by replacing the glass tubes by glass rods, and the joints were made tight with paraffin. In 5 months, the crystals were melted into a mass; and in a year, the whole of the chloride had been transformed into metallic gold, with occasional nodules of chloride through it; but the whole of it could be readily amalgamated.

"In order to ascertain the effect of different organic substances on salts of gold in solution, 5 portions of 50 c. c. each of a solution containing 0·5 *grm.* of chloride of gold were treated in different ways. The first was covered with 1 c. c. of petroleum. In the second, ½ *grm.* of cork was placed; in the third, ½ *grm.* of peat; in the fourth, ½ *grm.* of leather; in the fifth, ½ *grm.* of leaves. These solutions were put in a dark place, and were left for 3 months before examination. When the solution containing the petroleum was brought to the light, the liquid had lost its colour, and there were suspended in it a number of very fine and long crystals of gold, distributed nearly uniformly from the top to the bottom, and floating almost perpendicularly in the water. They had the appearance of the hexagonal crystals described by Professor Chester. As soon as the liquid was agitated, they fell to the bottom. The solutions containing the cork, leather, and leaves had also been rendered colourless, but the gold had entered into these substances, replacing the organic matter, so that they were pseudomorphed into gold. The solution in which the peat was placed was also colourless; but the gold was precipitated in the form of very small mammillary masses, recalling perfectly the form of nuggets.

"To ascertain the degree of solubility of gold, a quantity of pure spongy gold was prepared, and placed in a variety of solutions. Some of these were left exposed to the air; others were sealed at the ordinary temperature and pressure of the air for periods of 6 to 8 months; others were exposed to heat and pressure under varying conditions in an air-bath, arranged in such a way that the temperature could be kept constant for a number of hours at a time. Many of these last tubes burst after the liquid had acquired a tint. Of some of these, the contents were entirely lost; of others, a sufficient quantity of the liquid was left to test for gold.

"Solutions of salt, sulphate of ammonia, chloride of ammonium, chloride and bromide of potassium in sealed tubes, after 8 months, gave no reaction. Heated for 5 hours at temperatures varying from 150° to 200° C. (302° to 392° F.), none of them, except the bromide of potassium, gave any reaction, and that reacted very strongly. In the sealed tubes, the solution of salt, in which a few drops of nitric acid had been placed, reacted for gold; the iodide of potassium gave no immediate reaction, but when evaporated to dryness left a purple residue, soluble in bromine, which reacted for gold. Heated to a temperature of 100° to 170° C. (212° to 338° F.), the iodide of potassium tube gave a reaction for gold not much stronger than the solution before heating.

"A solution of commercial nitrate of ammonia, which contained some chloride of ammonium as an impurity, kept in an open tube at the ordinary temperature and pressure for 4½ months, coloured the solution bright-yellow, and reacted strongly for gold. Two solutions were made, each containing 5 *grm.* of nitrate of ammonia and ½ *grm.* of chloride of ammonium in 200 c. c. of distilled water. One of the solutions was left in an open room and the other put in a dark place, and left for 11 days. At the end of that time, both reacted strongly and with equal intensity for gold.

"Pure sponge-gold was then placed in the following solutions, contained in sealed tubes at the ordinary temperature and pressure for 3 months. Sulphide of ammonium produced no change and no reaction. With sulphide of potassium, a black precipitate was formed, and a strong reaction for gold was given by the liquid. Sulphide of sodium gave a black precipitate and a strong reaction for gold. Cyanide of potassium gave a yellow solution, a brown precipitate and smell of ammonia, and a strong reaction for gold. Chloride of magnesium, after nearly 3 months, gave a gelatinous precipitate, but no gold. Sulphate of soda, after the same length of time, produced no change and no reaction. The sulphate of copper produced no change after 2½ months.

"Spongy gold was then put into solutions of the following substances, and heated for 6½ hours between 145° and 180° C. (293° to 356° F.). Sulphide of ammonium showed no apparent change, but reacted strongly for gold. The solution of sulphide of potassium attacked the glass strongly; it looked greenish, and the liquid reacted for gold; a black precipitate was formed, which was dissolved in bromine, and reacted for gold. The solution of sulphide of sodium acted slightly on the glass, and acquired a greenish tint; a pink film was found on the glass, and a slight precipitate was formed. This film reacted slightly, and the solution very strongly for gold; there was not enough of the precipitate to examine. The solution of chloride of magnesium attacked the glass strongly, from which scales fell, but no gold was dissolved. The solution of sulphate of soda gave a cloudy, flocculent precipitate, but no reaction for gold. Commercial sulphuric acid and solutions of sulphate of potash, iron, and manganese gave white scales, but no reaction for gold. Solutions of sulphate and nitrate of soda gave no change and no reaction. The solution of permanganate of potash produced no reaction. In the solution of cyanide of potassium, the brown precipitate which was formed in the previous experiment dissolved, reducing the gold in the solution so that no gold was found dissolved.

"A mixture of nitrate of silver and sulphuric acid produced no change after 2 months. A mixture of the sulphates of potash, iron, manganese, and commercial sulphuric acid produced no change after 2 months. The permanganate of potash and sulphuric acid gave a black precipitate and coloured the liquid slightly pink, but gave no gold.

"In order to test the effect of organic matter in solution, ½ *grm.* of chloride of gold was placed in 2 *litres* of Croton water in two large bottles. One of these was left exposed to the sunlight, and from this all the gold was precipitated in less than a week; the other was placed in a dark room and left there; at the end of 8 months, a small amount of gold was precipitated. When solid organic matter was placed in the bottle, the precipitation was quite rapid; and when the bottle was then brought into the sunlight, all the gold was precipitated in about 48 hours.

"To ascertain the effects of the different soils on weak gold-solutions, ½ *grm.* of chloride of gold was dissolved in 10 *litres* of filtered Croton water, and made to pass continuously over the 3 mixtures given below arranged in glass funnels. The apparatus was so arranged that the liquid would flow drop by drop on the filters :—No. 1 contained 30 *grm.* of quartz sand; No. 2, 20 *grm.* of sand and 10 of soil; No. 3, 30 *grm.* of magnetic iron sand and 10 of quartz sand.

"The filters were left exposed in a room where there was considerable dust arising, and where there was also the smoke from passing trains. In 2 days, most of the gold had been precipitated in the filters, and the water had a greenish look. Then ½ *grm.* of chloride of gold was dissolved in 10 *litres* of distilled water, and filtered in the same way over 30 *grm.* of quartz sand, a mixture of 20 of sand and 10 of soil, and a mixture of 10 of sand and 30 of magnetic sand. These filters were carefully covered so as to prevent any dust settling on them, so that they were protected from all organic matter except such as was contained in them. At the end of 2 months, the clean sand and the mixture of magnetic and clean sand had reduced a small quantity of gold (a little more in the latter than the former) in concretionary shapes, which, owing to the rapidity of the action, were not coherent, but could be crushed with the pressure of the finger. In the mixture with the soil, the whole had been reduced, and was distributed through the sand as an impalpable powder, no indication of any concretionary form being observed.

"The attempt was then made to dissolve gold in a manner similar to that which was supposed to take place in nature. For this purpose, filters were prepared of 30 *grm.* each of clean quartz sand; in one of these 1·161 *grm.* of sponge-gold was placed and carefully mixed with the sand; in each of the other two, ½ *grm.* of very fine gold was mixed. Over the sponge-gold, 10 *litres* of distilled water, containing 30 *grm.* of common salt and 5 *grm.* of nitrate of soda, was made to filter constantly for 2 months; but no observable change took place. For the second solution, 6 *litres* of Croton water were taken, in which 9 *grm.* of nitrate of ammonia and 1 *grm.* of chloride of ammonium were dissolved. This was made to filter constantly for one month, but no gold was dissolved. For the last experiment, 1 *grm.* of nitrate of ammonia and 9 *grm.* of chloride of ammonium were used, but no gold was dissolved.

"It was the intention to continue these filtrations for 6 months at a time, and with all the conditions of natural waters, but the difficulty of making the experiments continuous decided the abandonment of them after a number of the other results had been obtained. The failure to dissolve gold in this short time does not prove that there is no action, as the other experiments show. An amount equal to a little less than that in sea-water might easily escape detection. In these experiments there is lacking the certainty that all the conditions necessary to success will be fulfilled. It was found in one of the experiments, made in the early stages of the investigation, that the fine dust circulating in the room was sufficient to precipitate the gold from a dilute solution. All these researches had to be made in a room to which many persons had access, and it is quite possible that the organic matter precipitated the gold in these last experiments as fast as it was dissolved; for in the experiments for the production of the placers the organic matter did deposit the gold in the sand. It is greatly to be regretted that these experiments could not have been made in the complete absence of dust.

"In order to test the effect of organic life in such solutions, a plant was watered with a very weak solution of gold, but, as is often the case in such experiments, the plant died of too much watering. In the anxiety to produce the kind of absorption by plants described by Durocher and Malaguti, the experiment was made a failure by too much enterprise. The examination of the ashes of the plant showed a small amount of gold, but most of the gold precipitated was in the soil around the plant, being thrown down there by the organic material in the earth. This experiment indicates the origin of the thin plates of gold which are sometimes found in the grass roots of certain placer countries.

"It will be observed that in almost all the cases where gold was dissolved, chlorine and some nitrogenous substances were found together in the presence of alkaline waters. These same conditions are favourable also to the separation and solution of silica. It has been proven by these experiments that the alkaline sulphides act on gold as well as the substances enumerated above, and it is quite easy to imagine the conditions under which the gold, already in solution in excessively small quantities, coming in contact either with solid or liquid organic matter, may precipitate all the metal.

"In Grass Valley, California, I have known of gold being thrown down in the filter of a Plattner's vat by the organic matter contained in the very impure water used there for the solution of the gold rendered soluble by the action of the chlorine. The filter was full of metallic gold, and there was no means of ascertaining how much of it had been lost. Several oz. of a brown deposit were taken from it, which was nearly pure gold. This cause of deposition, and of loss in large operations, has, I believe, been entirely overlooked. It is quite easy to explain the presence of gold in alluvial sands by the action of sunlight alone on the waters containing the gold in solution ; and to account for the gold on the bed-rock, by the solutions coming in contact with organic or mineral matter, such as the lignites, fossil woods, or the pyrites, which is everywhere found in deep placer deposits. The waters not being able to pass the bed-rock, remain there in contact with the organic matter until all the gold is precipitated. The same would be true of the decomposing rocks, or of slaty strata coming up to the bottom of the deposit at an angle. The deposition would be rendered much more rapid by any electrical currents that might pass through the strata.

"In all of these phenomena, time, which in the operations of nature is unlimited, is one of the chief factors. In any laboratory experiment, the limit of time must of necessity be short, but there is no such limit in nature. That this solution goes on on a large scale there is every reason to suppose. That it may be connected with vein phenomena the California nugget shows, since in this case both the formation of the quartz and of the nugget are evidently posterior to that of the blue gravel.

"It will be seen from these reactions that many of the conditions favourable to the solution of gold are also favourable for the solution of silica, and that, as Professor Kerr shows, the rocks may be actually decomposed and the gold deposited, forming in this way shallow deposits called veins, in which the gold disappears entirely beyond a few ft.

"Nothing is more likely than that the infiltration of water through rocks undergoing decomposition, of which there are enormous quantities in the gold-region, should take up the alkalies, and, slowly passing over the gold, should dissolve it. The composition of these alkaline salts would depend on the nature of the rock through which the waters passed, but it is more than likely that they would be mixtures of many of the compounds likely to attack the gold and carry it off in solution, and not alkaline carbonates and sulphides alone, although these would be likely not only to be present, but to be powerful agents in carrying on the work of solution. In some cases, the decay of the rocks is so rapid that the phenomena may, as it were, be caught in the act. The agencies producing the decomposition of the rock, penetrating it beyond the limits of local drainage, and carrying off the soluble parts, leave the débris in a condition easily penetrated by the infiltrating solutions, and ready to receive any deposit which these solutions may from any cause leave behind them. A source of these deposits in the deep placers of California is the trap which sometimes covers the old river deposits to a depth of 150 ft. In the deep placers, these waters would be capable of holding the gold in solution until they met some decomposing element, such as particles of metallic compounds, native metals, or organic matter, which is always present in large quantities in the deep placers. If a nucleus of metal were present, the gold would be precipitated on it, and if none were present, then the gold would come down as a powder, each grain of which, however small, would serve as a nucleus for future aggregations.

"Admitting the solutions to be even more dilute than the sea-water near the coast of England, yet unlimited time and quantity would evidently produce these effects, re-distributing the gold. Iodine, which is a solvent of gold, is found in many of the plants of the gold-region, and in considerable quantities in sea-water. Sonstadt supposes that gold is kept in solution in the water of the sea by the slow rate at which iodate of calcium is decomposed in the sea-water of the temperate zones, but suggests that where the decomposition of the iodate, whose presence is necessary to keep the small amount of gold in solution, is very rapid, as in hot countries, the liberation of the nascent iodine, and consequent rapid solution of the gold, and subsequent precipitation by organic matter, is quite sufficient to account for the great richness of the gold-deposits of tropical countries.

"It seems by the experiments already cited, to be clearly proved

IMAGE EVALUATION TEST TARGET (MT-3)

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that gold is not only not insoluble, but that in nature it is constantly being dissolved out of the rocks and placers, the waters of filtration dissolving out of the rocks in their passage through them all the materials necessary for the solution of the gold, and carrying it in very dilute solutions until it meets some substance that precipitates it. It seems to be proved that when the action is slow and localized, we have the phenomena of placers with large or small nuggets and irregularly shaped pieces; and when the action is rapid, we find the gold in small particles distributed through the sands. We have reason to suppose that these phenomena are now taking place in such a way as to concentrate the gold by infiltration and precipitation in the tailings of mines which cannot be concentrated by mechanical means. Some of these phenomena can be accounted for by the simple action of sunlight; but others, mostly those of the deep placer deposits, have their cause in the large amount of organic material contained in them. The use of a charcoal filter to precipitate the gold from relatively concentrated solutions, in one of the recently invented metallurgical processes, is a very suggestive idea of the means nature may have used on an immense scale on very attenuated solutions.

"The same conditions which cause the solution of gold in certain cases cause also the solution of silica. This explains the phenomenon of mammillary and apparently water-worn nuggets (like that from Placer county) encased in quartz, while both the gold and the quartz have been formed posterior to the blue gravel. It also explains the presence of 'putty stones,' as the soft pieces of decomposed rock constantly found in placer deposits are called. Many of the causes which produce the precipitation of the gold would also produce the reduction of soluble sulphates to insoluble sulphides, the gold being retained in the mass. This would account for the almost constant presence of gold in pyrites, or the occurrence of some of the copper-ores of Texas in the form of trees, the ore containing both gold and silver; also for the constant presence of gold in the iron-ores of Brazil, the so-called *jacutinga*, and for the presence of trees transformed into iron-ore carrying gold in some of our Western States. In many of the deep placers of California, the heavy cap of basalt is quite sufficient to account for many of the phenomena which occur not only beneath but around it.

"The fact that gold has not as yet been found in potable waters may be simply due to the extreme difficulty attendant on its detection in minute quantity. It is more than likely that many of the geological phenomena on a large scale were produced by very dilute solutions or very slight forces acting for a very long time. How far the electrical currents of the earth may have been a factor in these phenomena it is impossible to surmise. It is, however, more than probable that they were the result, not of one alone, but of all the causes mentioned, and perhaps many others which have as yet escaped our attention. No single agent is so powerful a solvent of gold as chlorine. Very few drainage-waters are free from some compound of it, and no soil is without the nitrogenous materials necessary to set the chlorine free, and therefore capable of attacking the gold and rendering it soluble. The experiments show that a trace of it is quite sufficient to dissolve enough gold to colour a solution so that the eye can detect it after a few weeks' exposure.

"In the nugget of Placer county, it would have been impossible for either the gold or the silica to have got into its position except by solution. The iron of the blue gravel in this case seems to have been the first cause of precipitation, and subsequently the gold itself was an active agent in increasing its own weight. The general absence of crystals, and their rounded edges where they are found, can be easily accounted for by the fact of the rapid action possible in the placers. The readiness of filtration through the easily permeated gravel causes the gold to precipitate so rapidly that there is no time for any but a mammillary deposit; while in vein deposits, the extreme slowness of the deposition allows the gold to assume a crystalline shape. When we consider that two-thirds of all the gold produced in the world comes from alluvial deposits, it seems difficult to account for its presence in the sands in any other way than by solution."

The last writer to be quoted on this subject is Prof. J. S. Newberry, whose paper on the Genesis and Distribution of Gold was published late in 1881. It runs as follows:—

"Gold occurs in three classes of deposits: 1st, placers; 2nd, segregated quartz veins in metamorphic rocks; 3rd, in fissure-veins, or repositories connected with them, where it is mingled with the ores of iron, lead, tellurium, silver, copper, &c.

"Placer Deposits.

"Nine-tenths, and possibly ninety-nine hundredths, of all the gold which has come into the possession of man, have been obtained from superficial deposits. These are called *placers* by the Spaniards, from whom we have adopted this as we have so many other mining terms.

"The gold here occurs in beds of sand, gravel, and boulders, which have plainly been washed down from higher ground, usually from neighbouring mountain slopes, composed of metamorphic rocks, containing auriferous quartz veins. This relationship is so constant that most persons who have observed or read much of placer-gold deposits have been satisfied with the simple and obvious inference that the gold has been derived from the erosion of higher rocks and the breaking down of quartz veins, the detrital materials having been sorted by water according to their specific gravity. Probably this view would have been universally accepted, the array of facts in its support is so convincing, if it had not happened that men are so constituted that it is impossible for all to think alike on any subject. Among other fruits of this constitutional heterodoxy is the coinage of a new theory to account for the genesis of gold in placers, namely, that the grains and nuggets are formed where found by precipitation from chemical solution.

"The facts by which the advocates of this theory have attempted to sustain it are: 1st, the rarity of nuggets or gold masses of any considerable size in quartz veins; 2nd, the greater purity of the fine gold of placers than that of the neighbouring veins; 3rd, the frosted character of the surface of some gold nuggets; 4th, instances of deposition of gold in organic substances buried in the gold placers; and 5th, the solubility of gold as proved by laboratory experiments.

"In arguing from these facts, it is stated that nuggets of gold of large size have been not unfrequently met with in all the great placers: such as the Sarah Sands and Welcome nuggets of Australia, which weighed respectively 233 and 184 lb.; the great nugget from Miask, in the Ural Mountains, which weighs 96 lb.; and others ranging from 25 to 50 lb., taken from the placers of Australia, New Zealand, and California; while 'no masses of gold of anything like the size of these have been found in quartz veins.' This latter statement is, however, erroneous; for the largest mass of gold yet found on this continent was taken from a quartz vein in the Monumental mine, at the Sierra Buttes, 12 miles N. of Downieville, Cal. It weighed 95½ lb., and is said to have been originally larger, weighing 140 lb. This discovery is well authenticated, and is reported in detail in Professor Raymond's Report on Mines and Mining for 1870 (Ex. Doc. No. 207, page 63). This, then, was one of the largest nuggets of gold found in the world, and proves that large nuggets can and do occur in quartz veins. Nor is this rarity of nuggets in quartz veins any proof of the truth of this new theory; for it is certain that the amount of nugget-gold taken from mineral veins is in fair proportion to the whole gold yield of such veins when compared with the proportions of nugget- and dust-gold in the placers. When it is remembered that from the slopes of the Sierra Nevada, over large areas containing auriferous quartz veins, a sheet of material, perhaps thousands of feet in thickness, has been removed by erosion, it will not be surprising that a considerable number of masses of gold have been taken from the resulting débris; and when we compare the insignificant excavations made by man in quartz veins with the gigantic mining operations of nature, we can only wonder that he has met with any of these large and rare masses of gold. The nugget argument, therefore, has no support, and falls to the ground.

"It is true, as has been asserted by the advocates of the chemical theory of the genesis of gold, that the fine gold in some places is of higher grade than that of the neighbouring quartz veins. This difference is, however, not marked, and something of this sort was inevitable, from the fact that all gold in quartz veins and placers is alloyed with silver. When minutely divided, and exposed to the action of chlorine and other agents which dissolve silver—so generally prevalent in the atmosphere and superficial deposits that silver is never found there in the metallic state,—some portion of the silver would naturally be removed from the surface of the particles of gold.

"It should also be said that the fine gold of placer deposits is usually purer than the coarse gold and nuggets, and the reason is, that the scales and fine grains of gold present more surface to be acted on by the agents which remove the silver. This process, which is essentially that called 'pickling' by the jewellers, with the fact that gold itself does not perfectly resist chemical agents, also affords an explanation of the frosted appearance which the surface of some placer-gold exhibits, and which has been hastily taken as proof that all such masses were chemically precipitated.

"Gold is usually said to be soluble only in aqua regia, and the idea is prevalent that it would remain for ever unaffected by any of the chemical agents in nature's laboratory. This is, however, far from true, as by the experiments of modern chemists it has been shown that it forms a great variety of chemical combinations. J. P. Pratt, epitomizing the results of his experiments, says (*Journal de Pharmacie et de Chimie*, August 1870): 'Gold can be readily oxidized and salified by oxacids. There exists a liquid and volatile chloride of gold containing more chlorine than the sesqui-chloride. There exists, likewise, a sesqui-oxide and a carbonate of gold; and lastly, gold behaves in many instances like some of the other metals.' While all this is undoubtedly true, and it is also true that in the gossans of some of our Western mines gold exists in other than metallic form, these facts lend no confirmation to the theory of the chemical origin of placer nuggets. A more interesting fact, proving the solubility of gold by natural processes, is reported from the placers of California, namely, that the bark of some of the tree-trunks found buried in the blue gravel was largely replaced by iron-pyrites, which was rich in gold. Hence, we cannot deny that some gold has been deposited in the placers from solution; but this certainly does not include the nuggets and gold-dust. The facts which distinctly militate against that theory are briefly as follows:

"First. Deposits of placer-gold are always found adjacent to and lying below districts traversed by auriferous veins, and nowhere else.

"Second. The areas where the quartz veins occur have certainly suffered great erosion, and mechanical forces have there been in action tending to break down and comminute the quartz, and to liberate and wash the contained gold.

"Third. The conditions in which the placer-gold is found—namely, mingled with rolled fragments of quartz and in the irregularities of the surface of the bed-rock, where a washing process on a large scale has been in action, and where such washing processes would have left it—prove the accumulations of gold to be mechanical rather than chemical. A deposit from chemical solution would not thus be circumstanced and localized.

"Fourth. The distribution of gold in placer deposits is also demonstrative of its mechanical origin; for in all cases known to me the nuggets and coarsest gold are found nearest the outcrops of the quartz veins that have supplied them; while the particles become gradually finer and finer as the line of drainage is followed from this point. Hundreds of instances of this kind might be cited—enough, indeed, to form the basis of a mechanical law in itself an unanswerable argument to the chemical theory.

"Fifth. Nothing is more common than to find, in the placers, pebbles and fragments of gold-bearing quartz, which must have been derived from the neighbouring veins, and most of the nuggets have more or less quartz, just like that of the veins, still adhering to them.

"Sixth. The surfaces of nuggets almost always bear incontestable evidence to the battering they have sustained. They are generally rolled and rounded, and the surface is such as could be produced only by blows and friction. The cases where the surface of the nuggets is rough and frosted, as though from partial solution, are extremely rare, and afford no support to the chemical theory.

"Seventh. If the gold of placers were deposited from solution, we should necessarily find much of it crystallized, and forming strings and sheets running through the porous material; whereas, as a matter of fact, crystals are never found in placer-gold, nor are sheets or threads. Scales, grains, pebble-like nodules, round, battered masses, these are what we find; in other words, sand, gravel, and boulders of gold formed and transported by mechanical means.

"I cannot better illustrate the occurrence of gold in placers than by describing an isolated placer I have recently visited, which combines all the normal features of this class of deposits, and bears, in unmistakable characters, the record of its history. It is located at Osceola, Nev., and lies on the west flank of Mount Wheeler, said to be the highest mountain in the State. The central mass of Mount Wheeler is granite, but on its flanks occur upturned and metamorphosed Palæozoic rocks, quartzites, slates, and limestones. A spur, which extends N. from the main peak, consists at its N. extremity of high, rough, and ragged masses of quartzite. These are succeeded on the S. by a belt of talcose slate several miles in length, forming a ridge which rises 4000 ft. above Spring Valley, its W. boundary. At its S. extremity, the slate belt is overlain by limestone. All these rocks are cut by veins of quartz, but those in the quartzite and limestone seem to be barren. The quartz veins in the slate belt are, however, numerous, and many of them are rich in gold.

"In the course of ages, the slate area has been extensively worn away, forming a 'cirque,' or semicircle, drained by several gulches, which combine below in one, and through which all the material removed from the mountain side has been spread over the slope to the valley below. In some places, the mass of débris is 300 ft. or more in thickness; above, it is narrowed between ridges of rim-rock, below spread out into a fan-shaped delta. The detrital material consists chiefly of rolled boulders and pebbles of quartzite and vein-quartz mixed with sand and a cementing clay derived from the decomposition of the slate. All this contains gold; near the head of the gulch, that which is coarse; that below becoming finer and finer toward the valley.

"The climate of this region is now excessively dry, no water flowing through the gulch, except during a week or two in the spring, when the snows are melting on the mountain above. The temporary streams thus formed have cut narrow channels through the beds of gravel and boulders in the upper part of the gulch to the bed-rock below, only in the loose material. These modern channels have revealed the existence of others that are much older and broader, now filled, and in places deeply buried. These old channels would seem to have been produced at a time when the climate was more moist and the flow of water from the mountain much greater than now. As usual in such cases, the old channels are rich placer ground, the gold having accumulated in the depressions of the irregular bed-rock.

"The number of nuggets and the quantity of coarse gold taken from this placer is remarkable. The largest nugget found weighed 24 lb., and many others have been met with, weighing ½ to 2 lb. At the time of my visit, two nuggets, weighing over 10 oz. each, were purchased, which had been found by one man on September 15th. Between $200,000 and 300,000 (40,000 to 60,000*l.*) have been taken from this placer within the last 4 years, all by hand labour, and for the most part during the brief interval when a little water was flowing down the gulch. The nuggets have all been found toward the head of the gulch. Many of them have vein-quartz still adhering to them, and their derivation from the quartz veins which crop out on the mountain side above cannot be doubted. The whole of this placer has been purchased by parties who are about to bring water on to it from streams which drain the S. slope of Mount Wheeler. These streams run in gulches, which have the same general character with that at Osceola; but none of them contains gold, simply because the slopes they drain are not composed of auriferous rock.

"The significance of the facts I have given, and their bearing on the question discussed on the preceding pages, may be briefly summed up as follows:—Mount Wheeler is a very high mountain, which, though located in an exceedingly dry region, has through ages received on its summit sufficient precipitated moisture to form torrents that drain and have deeply scored its different sides. The material excavated is all spread in the vicinity, forming slopes of gravel and boulders at the mouths of all the gulches.

"In one of these gulches, the detritus is rich in gold; in all the others, it is barren. The rich one has received all the débris from a portion of the mountain, composed of talcose slate, cut in every direction by auriferous quartz veins. The other gulches contain no gold, and there are no gold-veins at their heads. In the rich gulch, the gold becomes coarser and coarser toward the head as the outcrops of the quartz veins are approached. When to this is added that not a crystal of gold has been found in this placer, nor any gold that could be fairly considered a chemical deposit—but, on the contrary, all the masses are rolled and battered, often with adhering quartz—we have an array of evidence in favour of the mechanical deposition of the gold which cannot be gainsaid.

"Segregated Veins.

"Most of the quartz veins which carry gold belong to the class of what are called segregated veins. These occur only in metamorphic rocks, are lenticular sheets, limited in depth and lateral extension, and generally showing little of the banded structure so characteristic of fissure-veins. They consist mainly of quartz, in which the gold is sometimes free, but more commonly contained in iron-pyrites, with which yellow copper is often associated. Sometimes the gold is not strictly confined to the quartz veins, but extends more or less into the enclosing rocks, which are oftener than otherwise magnesian slates.

"The gold in segregated veins would seem to be indigenous to the formation in which it occurs, and not, as in fissure-veins, to have been derived from some foreign source. It is usually supposed that, before they were metamorphosed, the rocks which enclose the segregated veins contained gold generally, though sparsely, disseminated through them, and that, in the process of the segregation of the siliceous matter to form sheets of quartz, the gold was somehow gathered and concentrated by it.

"Sir Roderick Murchison, guided by his study of the gold-deposits of the Ural Mountains, supposed that auriferous quartz veins were confined to Palæozoic rocks, but that the gold-impregnation had taken place at a comparatively recent date. It was demonstrated, however, by Professor Whitney, in the prosecution of the geological survey of California, that the metamorphic slates which carry gold in the Sierra Nevada are of Triassic and Jurassic age; and in the light of later observations, we may say that metamorphic rocks of all ages contain auriferous veins. Nearly all the great mountain chains of the world contain more or less of such veins, and as these mountain chains have been the great condensers of moisture, and erosion has been constantly wearing down their slopes, placer deposits have been formed which have supplied most of the gold yielded by the earth to man. As it can be procured from them by the simplest methods, the work of its extraction was begun by prehistoric races, and the Altai, the Himálayas, the Ural Mountains, the Australian Alps, the Sierra Nevada, and the Rocky Mountains, have in turn contributed their millions to the treasuries of the world. These mountain chains are of very different ages, and we have abundant evidence that gold has existed in some of them from the earliest geological times. The oldest mountains of which we have any knowledge—the Laurentian, of Canada, now nearly removed by erosion—contained auriferous quartz veins that have supplied gold to all the successive formations which have been derived from their ruins. The gold-impregnation of the Laurentian rocks dates back certainly to the period of their metamorphism; and this was pre-Silurian, for the undisturbed Lower Silurian strata overlap and partially cover these gold-bearing rocks.

"In the same way, the gold at the Black Hills is proved to be pre-Silurian, since the Potsdam sandstone which abuts against the Archean nucleus of the hills in places contains rolled fragments of the Archean rocks, and gold washed from them in such abundance as to form rich mining ground—the so-called cement deposits of that region. The distribution of gold from the Archean rocks has probably been constantly going on from the Silurian age to the present day. This is shown in the almost universal dissemination of gold through the drift of New England, New York, Ohio, &c., where the superficial materials have been largely derived from the Canadian highlands. In Ohio, gold is found in the drift clays, sands, and gravels, and locally in as great quantity as in the poorer placers of California. There is little doubt that the mechanical sediments derived from the wear of the Archean rocks all contain gold, and since it has been proved that gold exists in sea-water, it has probably impregnated all the organic marine sedimentary rocks as well. In the subsequent metamorphism of some of these strata it has been concentrated in such a way as to produce auriferous quartz veins rich enough to be worked.

"From these facts it will be seen that there is no geological age which can be called the age of gold. It existed in the oldest rocks known, and from them and their derivatives, more modern rocks, it has been, and is now being, constantly distributed by both mechanical and chemical processes. Even some of the igneous rocks of the Western country are said to contain minute quantities of gold; and this is not surprising, if, as is supposed, much of our volcanic material is a fused condition of sedimentary rocks.

"Gold in Fissure-veins.

"As is well known, gold is a frequent constituent of the fissure-veins of the Far West. The ore of the Comstock vein has yielded about 47 per cent. of gold and 53 per cent. of silver; and it is probable that one-half of the so-called silver veins contain gold in sufficient quantity to be of practical value. In some true fissure-veins, gold is the only valuable ingredient, but more generally it is associated with several other metals. The Revenue mine, at Tuscarora, Nev., contains silver in the form of arsenical and antimonial sulphide, and gold in iron-pyrites frequently crystallized lining cavities. At Eureka, the ore occurs in chambers, which were originally filled from a solution issuing through fis[illegible] from below and deposited as argentiferous galena and auriferous py[illegible], the silver and gold being in nearly equal proportions. In the great veins of Bingham Cañon, and at the Cave mine, near Frisco, in Utah, the combination is the same, and as at Eureka, the sulphides have been decomposed to a spongy, rusty gossan. At the Bassick mine, in Colorado, gold exists free, or in combination with tellurium, and associated with zinc, copper, and iron. In all these, and many other cases which might be cited, the gold has been brought up in a hot solution impregnated with mineral matter far below, and deposited as the temperature and pressure were reduced. The formation of this class of auriferous deposit is well illustrated by the Steamboat Spring, in Western Nevada, where hot water, flowing out through fissures produced by subterranean forces, is depositing a siliceous veinstone, containing sulphides of iron, copper, oxide of manganese, and metallic gold. There is little doubt that, in the great mineral belt lying between the Sierra Nevada and the Rocky Mountains, where, in Tertiary times, volcanic activity was exhibited on a grand scale—sedimentary rocks upheaved and fissured in every direction, with great outflows of fused material—

hot springs, like the Steamboat, were everywhere busy, doing similar work. Bursting out at different places and times, and flowing from different sources, the solutions they carried and the ores they deposited varied greatly; but the methods of accumulation, transportation, and deposition were essentially the same, namely, the leaching of various rocks by steam and hot water under great pressure, by which silica and sparsely-disseminated metals were gathered and driven toward the surface, to be deposited as the pressure and temperature were reduced. Gold collected in this manner was unquestionably taken into chemical solution, and in the resulting vein deposits we find it in strings, scales, and irregular masses, often beautifully crystallized and associated with other crystallized minerals which are certainly chemical precipitates.

"We may sum up the teachings of geology in regard to the genesis and distribution of gold by saying:—

"First. Gold exists in the oldest known rocks, and has been thence distributed through all strata derived from them.

"Second. In the metamorphosis of these derived rocks it has been concentrated into segregated quartz veins by some process not yet understood.

"Third. It is a constituent of fissure-veins of all geological ages, where it has been deposited from hot chemical solutions, which have leached deeply-buried rocks of various kinds, gathering from them gold with other metallic minerals.

"Fourth. By the erosion of strata containing auriferous veins, segregated or fissure, gold has been accumulated by mechanical agents in placer deposits, economically the most important of all the sources of gold."

Geological Age.

In attempting a classification according to geological age of the gold-deposits now known to exist, the statements of various authors have to be taken at what they may be worth, and it is quite possible that future exploration in some fields will modify present views. For instance, it is often assumed that when veins cease upwards of the line of contact of two formations this is a proof that they existed before the deposition of the superior formation, which is by no means always assured. Again, in reference to the volcanic rocks associated with gold, it must be borne in mind that scarcely two geologists apply exactly the same name to the same rock; indeed, it becomes only too obvious that the present system of geological nomenclature is no system at all. With these facts in view, this section must be considered in some respects as tentative only, and it is to be hoped that its incompleteness will incite all interested to furnish more exact details of what they observe in future. The classification adopted is as follows:—

Metamorphic	Triassic
Laurentian	Jurassic
Cambrian	Cretaceous
Silurian	Tertiary, Miocene
Devonian	Tertiary, Non-Miocene
Carboniferous	Igneous.

METAMORPHIC.—"Metamorphic limestone" is stated by Probert to be the country-rock of the celebrated Richmond mine, in Nevada. Russians ascribe the Siberian alluvial gold to the ferruginous quartz of the metamorphic schists. In Hayti, every stream running through the metamorphic rocks in the immediate vicinity of masses of syenite carries gold, while those running exclusively in syenites, or at a great distance from them, are without the precious metal (p. 192). The gold of India is mainly derived from quartz reefs traversing metamorphic and sub-metamorphic rocks, and occasionally from gneiss, chloritic schists, and quartzites showing no quartz. The placer gold of Yesso, Japan, is derived from metamorphic strata (p. 351). The mountains forming the water-shed between the Chirchik, Tersi and Talas rivers, in Siberia, all of which carry gold, are mainly composed of metamorphic schists, veined with diorite, syenite, and quartz (p. 377). The prevailing formations of the Yeniseisk gold-fields, Siberia, are metamorphic schists, clay-slates predominating. The gold of the Trans-Caucasus is of metamorphic origin. That of New Caledonia is found in mica-schists.

According to Prof. Newton, the gold-ledges in the schists and slates of the Black Hills of Dakota are of Archæan age (Archæan being the term founded by Dana for the older non-fossiliferous strata, mostly composed of crystalline and metamorphic rocks—granite, syenite, gneiss and micaceous, talcose, hornblendic, and chloritic rocks), and were formed during the folding of the metamorphic rocks. The whole area of the gold-field in the Black Hills was, at the time of the upheaval of the range, covered by the Potsdam [Cambrian: Lower Silurian] and subsequent formations. It is probable that the Potsdam conglomerate, formed by the primary erosion of the metamorphic rocks and their enclosed auriferous quartz ledges, contained considerable quantities of gold, and by the disintegration and denudation of this conglomerate since the elevation of the Hills, the gold which it contained has been set free and concentrated anew in the placer gravels. This may in part account for the richness of some of the older and more elevated gravel deposits along the valleys of the present streams.

Jenney considers the metamorphic rocks of the Black Hills as separable into two distinct groups, whose lithological characters are marked and persistent: a western series, or group of schists, and an eastern series, or group of slates, the line of separation being only imperfectly indicated. The western series consists of quartzose schist and garnetiferous, quartzose, and ferruginous mica-schists, together with some gneiss, chloritic and talcose (or hydrous mica-) schists, hornblendic schist, and quartzite. The whole series is coarse in texture and highly crystalline, and it contains many seams or veins of quartz traversing the schists conformably with the stratification, and having usually a swelling or lenticular structure. These veins are interlaminated, and are not often of any great width; they contain finely disseminated gold, and have probably afforded by their disintegration the larger portion of the gold found in the valleys and gulches. The granite masses are wholly within the area of the schistose rocks. The eastern series is composed of metamorphic rocks, distinguished from the western mainly by their exceedingly fine and compact texture, though, as shown by Caswell, their ultimate mineral composition is quite similar. The rocks are mainly micaceous clay-slate, clay-slate, silicious slate, and quartzite. The last forms persistent strata, 50 to 200 and sometimes 500 ft. in thickness, which may often be traced for long distances with little variation. The quartzite frequently contains seams or veins of interlaminated or ribbon quartz, and with them are associated large deposits of hematite or specular iron-ore, also interlaminated with quartz. Frequently the quartz seams are highly ferruginous, and in places they have been found to contain undecomposed pyrites. Unquestionably they are often auriferous. In many instances, the quartz veins are undoubtedly auriferous, and the larger portion of the gold found in the gravels of the Hills has originated from them; but by reason of its sparse dissemination in the vein-matter, specimens containing visible particles are not often met with. The very fine state in which the gold is found in the gravels of the southern end of the Hills is also an evidence of the fine state of division in which it occurs in the veins. The gold encountered in the ancient gravels of the Potsdam formation must be referred, together with that obtained from gravels of the most recent formation, to the quartzes of the Archæan as its source.

In some of the valleys in the northern end of the Hills, where rich deposits of placer-gold have been found, the bed-rock of the stream is Potsdam sandstone. The auriferous gravels may in such cases have been derived directly from the wearing down of the schists and slates on the upper courses of the creeks; but it is more probable that they came indirectly from the same source through the medium of the Potsdam. The streams which drain the Archæan area are concentrating the gold by a method not very dissimilar from that of the Potsdam waves, and it is reasonable to suppose that dirt which has been first rocked by the waves and then sluiced by the creeks will hold its gold in a more concentrated condition than that which has had the benefit of but one process.

Foote divides the metamorphic rocks of the known auriferous area of India (pp. 317–8) into 3 groups, distinguished by the local names of Dhoni, Kappatgode, and Surtur, while 2 other groups, the Gulduck and Mulgund, are apparently barren. Quartz reefs occur in all the series; but according to the natives, it is only streams draining the Surtur series that carry gold, and these lie entirely in an area of chlorite-schists and diorite.

LAURENTIAN.—E. McCarthy (Min. Jl., July 1st, 1882), speaking of the three formations in which gold occurs on the African Gold Coast, mentions quartz reefs traversing the older rocks of clay and talcose slates and schists, upon which the second series of rocks (sandstones and conglomerates often so metamorphosed as to pass into gneiss) are laid, and in almost every case they are auriferous, while the more recent quartz reefs traversing the second series of rocks, and sometimes even the gravel beds, are non-auriferous. The older rocks he considers may be of Laurentian and Cambrian age. Williamson likens the auriferous rocks of Parahyba, Brazil, to the Laurentian of Canada.

CAMBRIAN.—Notwithstanding all that has been published by the various geologists who have studied the gold-region of Minas Geraes, Hartt considers that the exact succession of the different members of the metamorphic series lying just inside of the gneiss belt has never been satisfactorily worked out. The clay and talcose schists, the itacolumite, itabirite, and other associated metamorphic rocks of this region appear to him to be Lower Palæozoic in age. He has called attention to the striking resemblance borne by the clay-slates and associated quartzites to the gold-bearing rocks of Nova Scotia, and has suggested that they may be the equivalents of the Quebec group of North America. The gold-bearing rocks in Minas Geraes resemble the similar auriferous series of the southern Atlantic States, in which itacolumite occurs. Clay-slates with auriferous veins occur in other parts of Brazil besides Minas, as, for instance, in Goyaz, and in the vicinity of Cuiabá in Matto Grosso. These rocks are everywhere so metamorphosed, that all trace of fossils has been completely obliterated. The characters of the auriferous rocks are described on pp. 219–22, 229.

According to Selwyn, the gold-bearing series in Nova Scotia (pp. 85, 87) resembles the Cambrian and Lingula-flag series of N. Wales (pp. 739–44).

SILURIAN.—It is quite unnecessary to insist upon the gold-yielding capabilities of the strata of Silurian age, so long thought to be the only auriferous formation. Though its claim to a monopoly of gold-veins is now quite disproved, it maintains the first rank in point of importance in that respect. Ulrich remarks that in Victoria (pp. 644–5), the Silurian, as a whole, is the most important rock-formation to the gold-miner, on account of its containing the matrix of the gold in the countless number of veins, lodes, or reefs of quartz that traverse it—the number of those actually proved gold-bearing amounting already, according to Brough Smyth's Mining Statistics of 30th June, 1874, to 3367, and being still steadily on the increase, through the untiring prospecting energy of the miners. These reefs vary from less than 1 in. to above 100 ft. in thickness, whilst their longitudinal extent ranges from less than 100 ft. to several miles. Their mean strike is, in the Lower Silurian series, generally conformable to that of the strata; reefs that cross the latter being very scarce (Taradale and Stawell are the chief localities where cross reefs occur—one at the latter place being celebrated for its richness in gold). In the Upper Silurian are more exceptions to this rule; and it must also be remarked that this series is not by far as rich in genuine quartz-reefs, and those found—though on the average, perhaps, richer in gold per ton of stone—are not as thick and persistent as those of the lower series. The greater amount of quartz-gold produced by Upper Silurian districts comes from irregular blocks and veins that traverse, or are closely associated with, dykes of diorite-greenstone. Regarding the dip or underlie of the reefs, it varies at all angles between nearly horizontal and vertical, and coincides not only in most cases in direction with the dip of the strata, i. e., either E. or W., but its angle is often so nearly identical with that of the latter, as to impart to the reefs the appearance of interstratified deposits. If it were not for the frequency of lateral branches—"leaders"—joining the main bodies at all angles, both at their hanging- and foot-walls, they would in reality have to be considered as "layers" or interbedded deposits; but, as it is, they represent in these cases so-called "layer- or bedded lodes."

Another feature of importance is, that many reefs show, from the surface downwards, an endlong dip, or a dip in strike either N. or S., sometimes in both directions, whence follows an expansion in depth. Prominent amongst the former are the so-called "block reefs," i. e., reefs which in their longitudinal extent show frequent contractions, consisting, as it were, of a series of—in horizontal section—lenticular-shaped blocks, frequently of considerable thickness in the centre, which are connected at longer or shorter distances, sometimes by thin veins of quartz, sometimes by ferruginous clay-casings only, and each block dipping from its outcrop at a certain angle—rarely at right-angles—to the line of strike either N. or S., i. e., the blocks of one and the same reef, and generally of all the reefs in a district, show invariably the same direction of dip—northward being the most frequent. The expression, often used by Victorian miners, "that it requires a shaft of a certain depth, either N. or S. of an outcrop, to strike the 'cap' of a reef," refers to this feature, and will thus be easily understood. A peculiar and interesting occurrence are the so-called 'saddle reefs,' described in another section. As the term indicates, a reef of this class presents, in E. and W. section, the shape of a saddle, i. e., a generally very thick central part with a certain flat dip in strike, either N. or S. bends—whilst decreasing in thickness—sharply downward on either side; and of these lateral parts, the so-called eastern and western legs, one dips generally with the strata, whilst the other opposite one crosses them.

The mode of occurrence of the gold in reefs can be brought under the following main heads:—

1. The metal is equally distributed throughout the whole thickness and extent of the reef. This seems to be the rarest occurrence. Generally, richer and poorer places alternate, especially where the thickness of the reef changes, the contracted portions being mostly richer than the wider ones; but the contrary having also been found to be the case, in a marked manner in some reefs, no rule can be established in this respect.

2. It exists in irregular larger and smaller patches, both in strike and dip, throughout the reef. More frequent than the former.

3. It occurs most frequently in so-called "shoots," i. e., in stripe or band-like areas or portions of the reef of various widths, which dip at various angles, either N. or S. in strike; rarely at right-angles to the latter. Both the width and angle of dip of the shoots vary in each individual case generally but little, allowing thus tolerably accurate calculations to be made as to the depth at which a shaft, for instance, situated some distance from its outcrop, ought to strike such a shoot in the direction of its dip.

4. A not uncommon case, especially in strong reefs, is that the auriferous portions, either irregular patches or shoots, occupy only a certain width along the hanging- or foot-walls, more rarely along both walls, whilst the remainder of the reef is barren. Some exceptional cases have also been observed, however, of the gold being confined to a certain width in the centre of strong reefs, the quartz along both walls proving worthless. Most of these occurrences form structural features of the respective reefs, inasmuch as the gold-bearing portions represent separate bands, divided by thin black casings from the rest; they appear, in fact, different in date of formation from the latter, either older or newer, thus indicating a re-opening and successive filling of the reef fissures.

Touching the depth to which the gold extends in Victorian reefs, the hypothesis advanced by high authority in the early days of the gold-fields, namely, "that the metal would be found to quickly decrease in quantity, and entirely to disappear at a limited depth," has, fortunately for the prosperity of the quartz-mining industry, proved, in the main, incorrect. For depths of between 500 and over 1000 ft., at which payable stone is being worked in many mines already, and with no unfavourable signs, even in the deepest, of its termination lower down, can surely not be called limited. That the quartz becomes, on the average, poorer in gold with increasing depth from the surface seems, however, to be the case in a great number of the deep mines, though exceptions of an actual improvement are not wanting. In fact, in many deep mines, profitable working is at present only carried on by great economy and improvements in the system of mining and the machinery, especially that for crushing the quartz, combined with the gold-saving appliances; and last, though not least, by the saving and treatment of the auriferous pyrites—iron-, arsenical, and magnetic pyrites,—ores which generally appear at or beneath the water-level, and seem to increase in quantity in depth, whilst the free gold gradually decreases.

The yield of gold directly and indirectly drawn from Upper and Lower Silurian rocks in Victoria has reached approximately 60,000,000 oz., value 250,000,000*l.* Pegler places the gold area of French Guiana in Silurian. Most or all of that found in the Andes would seem to be of similar age. Probably the whole of the Siberian gold is derived from the Silurian limestones and schists, which are penetrated and in some places metamorphosed by granites, porphyries, serpentine and diorite. Part of the New Zealand gold-fields are in Lower Silurian hornblende rocks, and part in Upper Silurian Batow river slates (p. 521). Many of the Queensland reefs are in Silurian metamorphic rocks (p. 579).

DEVONIAN.—The gold-workings of the Devonian areas of North Gippsland have been ably described by A. W. Howitt. The localities in which the auriferous deposits are being worked are as follows:—(1) Lower Boggy Creek; (2) The Mitchell river, between Tabberabbera and Lindenow Flat; (3) Maximilian Creek.

It is a question of no less moment from an economic than of interest from a scientific point of view whether the gold found and worked in the "claims" of the above localities is of local or extraneous origin. If it is possible to show reasons for the belief that the gold is local, and not derived from the waste of Silurian areas, then an inference is justified that similar auriferous deposits may exist, and may be discovered, throughout these formations at a distance from the older Palæozoic rocks.

Howitt gives the following table of assays of alluvial gold from the above localities. The assays were carefully made before the blowpipe, and each one consists of the mean of two or more nearly accordant assays of the same gold.

COMPARATIVE TABLE SHOWING THE FINENESS OF ALLUVIAL GOLD FROM VARIOUS MIDDLE AND UPPER DEVONIAN LOCALITIES IN NORTH GIPPSLAND.

No.	Au.	Ag.	Oxidizable Metals and Loss.	Locality.	Geological Formation.	Character of Gold.
1	94·950	4·850	·200	Lower Boggy Creek ..	Upper Devonian, resting upon trappean porphyries	Fine, laminated, and scaly.
2	96·137	3·378	·485	Tabberabbera, 4 miles above Wentworth river	Middle Devonian, with Upper Devonian outliers	Fine, scaly.
3	96·322	3·668	·010	Ditto, 3 miles above Wentworth river ..	Ditto	Ditto.
4	96·340	3·660	..	Ditto, junction of Wentworth and Mitchell rivers	Ditto	Ditto.
5	97·174	2·174	·652	Ditto, 2 miles below Wentworth river ..	Middle Devonian, overlaid by Upper Devonian	Scaly, a few small quartz specimens.
6	97·070	2·386	·544	Mitchell river, above Glenalladale	Upper Devonian ..	Laminated and scaly.
7	83·872	16·128	..	Maximilian Creek, Upper Gladstone.. ..	Ditto, resting on older rocks	Nuggety and rounded.
8	84·214	15·571	·215	Ditto, Lower Gladstone	Upper Devonian ..	Ditto.

(1.) Lower Boggy Creek.—This stream, after leaving the Silurian auriferous quartz-bearing strata of its upper course, enters a tract where the bed-rock is a peculiar quartz-porphyry, and the only overlying strata, exclusive of marine beds of Upper Tertiary (Pliocene) age, belong to the Upper Devonian group. The gold found in Lower Boggy Creek differs completely in its physical character from that met with where the upper part of the stream flows over Silurian rocks. It is finely laminated or scaly, while that of the upper creek is coarse and nuggety.

In considering this question, it seemed to Howitt, from the facts with which he was then acquainted, that the gold found in Lower Boggy Creek might have been derived from the wearing down and rearrangement—in fact the "ground-sluicing"—of great accumulation of waste from the Silurian hills, when the later Tertiary coast-line extended far up the valley of Boggy Creek. As already noted, it is worthy of remark that the physical character of the gold found at Lower Boggy Creek differs very greatly from that of the Upper Silurian, and it is to be added that the change in character is coincident with the change in the formations, and that it entirely accords with the character of the gold found throughout the gold-workings in rocks of the Devonian age of the Mitchell from Tabberabbera downwards. These and other facts which will be shown in respect to other localities may require this hypothesis to be somewhat modified, by adding to the auriferous material also the waste of the Iguana Creek beds themselves.

(2.) Mitchell river.—Gold workings exist at the Mitchell river from some miles above Tabberabbera down to within 2 miles of the commencement of the wide valley of Lindenow Flat. The claims are all worked on the banks, on the points of the spurs, and, when the water is sufficiently low, in the river-bed. But they are much scattered, and, owing to the great difficulty experienced in constructing water-races for sluicing, the extraction of the gold is mostly performed by the primitive method of "cradling," and consequently does not remunerate miners as it otherwise would do. So far as it is possible to judge from the few claims opened, and from the surface indications seen elsewhere, there can be but little doubt that the whole extent of river mentioned is more or less auriferous.

This extent may be divided into three portions:—

(*a.*) Middle Devonian (Tabberabbera shales), with mere traces of the Upper Devonian.

(*b.*) Middle Devonian (Tabberabbera shales), overlaid by a great thickness of Upper Devonian (Iguana Creek beds); and

(*c.*) Upper Devonian (Iguana Creek beds).

The first portion (*a*) is situated about Tabberabbera, being perhaps 4 miles above and the same distance below the junction of the rivers Mitchell and Wentworth. The character and fineness of the gold found will be seen from the tabulated form given.

The second portion (*b*) extends down to near Cobbannah Creek, where the nearly vertical beds, which Howitt regards as belonging to the Tabberabbera shales group, dip out of sight. Three or four claims have been worked in this area, but no particulars as to results are available.

The third portion (*c*) may be said to extend down to Lindenow Flat. Claims have been worked in various places, and gold in small quantities also obtained in some branch gullies. Here the sole formation is the Upper Devonian, whose conglomerates, shales, and sandstones form the hills through which the Mitchell river has forced its course.

Howitt visited the claim of Turnbull and Howarth, near Stony Creek. The ground washed by them is along the narrow flat bordering the river. The "wash-dirt" consists of sand, gravel, and boulders, derived from the Iguana Creek beds. The nature of the ground necessitates cradling, and the proprietors informed him that in consequence they were unable to make more than 2*l.* per man per week. Were water available for sluicing in the usual method, the yield would be more than double. The character of the gold and its fineness are given in the table; in appearance, it is indistinguishable from that found at Lower Boggy

Creek or at Tabberabbera. Over the river, but slightly higher up stream, is the claim of Pope and Poore, on a point of land. The river being then up, Howitt was unable to visit it. Poore, however, informed him that the gold found was of two kinds—one of the usual scaly character, the other ragged and unworn. It is to be noted here that for many miles round there are, so far as known, no older rocks than the Iguana Creek beds.

(3.) Maximilian Creek.—At Maximilian Creek, the formation is essentially Upper Devonian. For, although in the upper workings at Blink Bonny Gully the underlying older nearly vertical quartzites have just been laid bare, they disappear very soon in following the creek, so that thenceforward down to Freestone Creek the only formation met with, being the bed-rock, consists, with a great felstone sheet of the alternating conglomerates, sandstones, and shales, of the Upper Devonian. The gold is in character nuggety, much worn and rounded, and of a low standard. Its physical appearance would suggest that it has travelled; but it seems to Howitt utterly incompatible with the laws of gravitation that such masses of gold could have been transported from the Older Palæozoic areas by the streams which have excavated valleys such as that of Maximilian Creek. These Older Palæozoic areas are to be found only at the source of Maximilian Creek, and have never yielded any gold, so far as known. Howitt can, however, conceive that all the appearances suggestive of transport of the gold would arise from a gradual subsidence of the masses as the valleys were excavated. There are no means of estimating the vertical height above present levels at which the matrix from which the gold has been derived may have been situated.

It is said further that quartz veins bearing some gold, both in the quartz, and free in the casing and rubble, have been opened at Maximilian Creek, in Long Pat's Gully, and at the Crystal reef, Stewart's Gully. A fragment of quartz containing gold was given to Howitt as from the former spot; but he has no personal knowledge of the facts, and gives these statements to be taken for what they may be worth. It may be, however, borne in mind, that quartz veins are not at all rare passing through the sandstones and conglomerates of the Iguana Creek group.

Howitt thinks the following deductions may be made from the above statements:—(1.) That gold is found in alluvial deposits which are derived from purely Devonian formations, as, for instance, the Iguana Creek beds. (2.) That the gold found throughout a great part of this area possesses certain physical characters and a common ratio of gold and silver within certain bounds.

This being the case, the question may be asked, why should it be regarded as necessary in Victoria to restrict auriferous deposits to the Lower Palæozoic rocks, and to exclude the Devonian formations from the gold-bearing series? The explanation may be, that the richest deposits have certainly been met with here in Silurian areas, or in granite tracts which once were covered by strata of that age. No doubt it is the Lower Palæozoic rocks which have here, as in many other countries, been richest in gold; but facts collected from other parts of the world now show that they are not exclusively so.

There are no good grounds for assuming that gold is confined to one geological formation, or that the production of auriferous quartz veins has been limited to any period. At all periods it is probable that the causes which have produced gold-bearing veins have been more or less active, and may be still in operation under conditions which we are unable to examine. But we may observe the effects produced by such causes in more recent time than the geological eras mentioned above. For instance, iron-pyrites of auriferous character occur in the leads of Ballarat, Clunes, Daylesford, &c., which show the shapes of roots and branches of trees, and are therefore of very recent origin.

It may be that much of the gold, if not all, found in these Devonian areas of Gippsland, has been derived from the conglomerates and quartz grits which are themselves the result of the degradation of older and probably Silurian strata. Some part of the gold of the Mitchell river is laminated, and may have been disseminated throughout the quartz conglomerates as one of their constituents, similarly to the gold which is found in spangles in the base of the conglomerates of the Carboniferous series of Nova Scotia. And it suggests itself that our Devonian conglomerates, or even the conglomerates of the Avon sandstones of Lower Carboniferous age, may be worth examination for such deposits. But another part of the gold is either ragged or else attached to small fragments of quartz. This gold would therefore seem to have been set free from veins *in situ*, and lends force to the statement that auriferous quartz has been found at Maximilian Creek.

It may hardly be necessary to point out that, in accordance with views which are now received among geologists as to the probable origin of auriferous quartz veins, there can be no sufficient reasons given why the quartz veins of the Lower or of the Upper Devonian strata should not also be auriferous. It was assumed formerly by some geologists, and the belief still lingers, that the granites and diorites have been the chief gold-producers, and that the auriferous quartz bands in the Palæozoic rocks are also the result of heat and chemical agency. But even the exponent of these views did not attribute the product of gold always to Palæozoic times. Sir Roderick Murchison states, in speaking of the Ural —"We are led to believe that in this region the noble metal, carried up by igneous rocks, was only brought together in rich veins at comparatively recent periods."

In Victoria, the position of the gold-bearing quartz reefs of the Lower Palæozoic rocks shows that they are anterior in age to the Upper Palæozoic formations, which rest unconformably upon the strata in which they are contained, and together with which they have been denuded.

Howitt considers it undoubted that Victorian auriferous quartz reefs are due to deposition from aqueous solution. The investigation of vein-quartz by means of the microscope shows that it still contains portions of the fluid menstruum in minute cavities. Sorby has found that the fluid in the cavities of vein-quartz often contains a very considerable quantity of the chlorides of potassium and sodium, the sulphates of potash, soda, and lime, and sometimes free acids; and he clearly states, as his opinion, that every peculiarity in the structure of the quartz of veins can be most completely explained by supposing that it was deposited from water holding various salts and acids in solution. It would follow that the associated minerals, and even the gold, have the same derivation. Bischoff, in his great work on Chemical Geology, says that there seems to be an intimate connection between gold and iron, either in the state of sulphide or oxide, and likewise between quartz and gold. A silicate of gold may be prepared artificially, and it appears that, under certain circumstances, it may be dissolved in sensible amount. The silica constituting the quartz associated with gold certainly originates from the decomposition of silicates in rocks, and it may be conjectured that the gold has the same origin, possibly existing as a silicate.

The occurrence of gold as small crystals and as capillary masses is indicative of processes of reduction from compounds, and its frequent occurrence in quartz indicates the deposition of such gold-compounds from the water that deposited the quartz. The accidental discovery made by Daintree (p. 759) that a speck of gold, lying in a solution of chloride of gold, increased to several times its original size after a small piece of cork had by accident fallen into the solution, suggests also that gold may be distributed throughout the meteoric waters as a chloride; and an experiment made by the great chemist, Bischoff, before quoted, shows that, in adding to a solution of chloride of gold a solution of silicate of potassa, if the resulting precipitate is allowed to remain undisturbed for some months under water, a decomposition takes place, and in the silicate appear minute partly microscopical specks of gold. In remarking on this, Cosmo Newbery says that, if this is the method by which the gold reached the quartz lodes, the origin of the silica is also that of the gold. Howitt therefore feels justified in believing that the auriferous quartz reefs have been deposited from aqueous solutions permeating—say, for instance—the Silurian strata, and it follows that we may expect to find similar deposits throughout those formations which have been similarly affected. Although not directly bearing on the Devonian formations, it may not be uninteresting to follow these suggestions a step further in enquiring to what depth the auriferous reefs of Victoria may possibly be expected to descend. Very many questions would have to be considered, and the subject is obscure and difficult of reply. Assuming, however, that the depth to which the now remaining strata of Silurian age descend below any given datum-line is comparable with the height to which the granites, which have invaded and cut off that formation, rise above that same level, we may at the same time arrive at a rude estimate as to the depth to which it may be expected our auriferous quartz reefs may descend.

Looking at the Gippsland mountains for an illustration, Howitt finds that Mount Baldhead may be taken as the highest granite mass south of the Silurian area of the Crooked river country, while to the northward of the Great Dividing Range the same auriferous tract extends to Mount Buffalo, which may be regarded as the nearest highest granite mass to the north. About the Crooked river, the Upper Dargo, and the Upper Ovens, no granite is anywhere visible at the surface; but, from the structure of the country, as well as on general geological considerations, it may be certainly assumed as existing beneath, at an undefined depth. Taking the heights of Mount Baldhead and Mount Buffalo as being 4000 to 5000 ft. above the river-levels at the Crooked river, and regarding those mountains as part of the rim of the granite trough or basin including the Silurian area, he roughly assumes that the depth to which the Lower Palæozoic formations there descend below the datum-level may possibly be equal to the height of the granite above it; or, in other words, that the denuded Silurian strata, in their folded and compressed condition, may possibly have a thickness of 4000 to 5000 ft. Such inference applied generally would lead to the belief that the auriferous quartz reefs of Victoria may extend to greater depths than human appliances can at present follow them.

The same consideration as to the origin of the auriferous veins in the Silurian formations would show that the presence of such in the Devonian rocks presents no improbability. These formations exhibit the effects of metamorphism, and of the extensive infiltration of silicious waters, although to a less extent than the Lower Palæozoic rocks.

That the Devonian formations are universally or richly auriferous is questionable; but Howitt does not in the least doubt that many other places than those now mined will be profitably worked for gold in the Iguana Creek group; and that for the future the Upper Devonian, or even the kindred Lower Carboniferous formations into which they appear to gradiate in Gippsland, will not be entirely avoided by prospectors as being barren.

The gold of Minusinsk, Siberia, is partly ascribed to Devonian strata (p. 410). Some of the New South Wales reefs, too, are in Devonian strata (p. 496). The Te Anau auriferous beds of New Zealand are doubtfully referred to Upper Devonian (p. 521). The Gympie and other gold-fields of Queensland are in Devonian (pp. 590–1). Some of the Cornish gold is ascribed to silicious bands in Devonian rocks (p. 727).

CARBONIFEROUS.—Mention has just been made of Howitt's belief that the gold of the Upper Devonian rocks of Gippsland may be found passing also into the Lower Carboniferous strata, into which they appear to gradiate.

Gold-fields have been worked in Queensland within areas where Carboniferous rocks are said to prevail.

According to S. Herbert Cox, the auriferous reefs and cements of the Tuapeka district, in New Zealand, are partially of Lower Carboniferous age. The oldest beds met with in the district are those which belong to the Wanaka formation of Captain Hutton. They consist chiefly of coarse-grained mica-schists, with frequent veins of quartz traversing them in all directions ; and in certain places they form the country in which quartz reefs carrying gold and other minerals have been found. In the district examined, the most notable places in which gold occurs in this formation are the hills around Waipori, and again at Beaumont, on the N.E. side of the Molyneux river ; but very little is known of the reefs in the latter locality. There are in connection with this formation beds of chert, &c., and these appear to be reproduced in the rocks which form the auriferous cements of the Blue Spur, and it seems probable that from them the auriferous cements just mentioned have derived their gold.

The Kakanui series, which is only, in point of fact, the higher beds of the Wanaka formation, consists of fine-grained mica-schists. But few quartz reefs have as yet been found in these beds of an auriferous character ; but one which is worthy of mention occurred between the Blue Spur (Gabriel's Gully) and Weatherstone's. This reef was worked for a short time, and yielded payable gold, but it was eventually cut off by a slide, and the mine was abandoned.

The auriferous cement deposits which are at present known, and of which some are worked, follow a N.W. and S.E. line, the Blue Spur being the furthest point to the N.W. at present known. Between the Blue Spur, which is situated at the head of Gabriel's Gully, and Weatherstone's, the next deposit to the S.E., is a narrow ridge of the Kakanui schists, and it is here that the quartz reef mentioned above occurred.

The next deposit of importance is Waitahuna, although a few patches of cement do occur between these points, and have received a certain amount of attention from prospectors. After passing Waitahuna in a S.E. direction, no work of importance has been done on these beds.

At the Blue Spur, the cements are enclosed in a trough, or, perhaps more correctly, a basin, as, in addition to the bed-rock on which they rest as in a trough, the schists to the N.W. and S.E. respectively rise to form hills of greater elevation than the cements themselves assume at the present time. The bed-rock on the N.E. side of the basin or trough is very steep, while on the S.W. side it is more shelving, the total thickness of the cements being certainly not less than 300 ft. An enormous quantity of this spur has now been removed. Formerly all the claims in this locality were sluicing claims, putting the whole of the cement through a process of ground-sluicing; but this has not in every case proved remunerative: besides which it has been shown that a good deal of gold, which might have been saved, was lost in this process, and accordingly several of the claims have now erected batteries, and crush the cement, in certain cases putting everything through the stampers, and in others only certain parts of the stone which are known to be somewhat richer than the general run of the deposits.

Passing over the ridge between Gabriel's Gully and Weatherstone's, no cements are met with until after crossing the summit; but on the spurs falling into Weatherstone's, beds or benches of cement have been found, which yielded in some cases a considerable quantity of gold, while in the gullies below them no gold was to be found. This fact would point to more than one rearrangement of the beds since the gold was originally deposited with the cements. At Weatherstône's, the cements appear again, covering a considerable area of ground, but lying much lower than the Blue Spur.

The cement has been traced all through the flat towards Lawrence, and at a place called the Mound a shaft has been sunk to a depth of 500 ft. through these cements; but it has not received further attention since the bottom was reached, so that probably the results obtained were not so satisfactory as could be wished. It is calculated that in the Weatherstone's field, 1½ dwt. of gold per ton would pay well, which, when it is considered that at the Blue Spur ½ dwt. to the ton is extracted, would appear probable.

At places the prospects of the wash-dirt are very rich, some returning 2 oz. 17 dwt. of gold per ton, and doubtless there is some richer even than this. It has, however, been ascertained by experience that the gold is by no means evenly distributed; but runs in patches without apparently any set rule, so that any estimate as to the richness of the deposit from mere assays is nearly, if not entirely, useless. The blue cements of

Weatherstone's are capped by red ones, which, however, are only due to the oxidation of the pyrites which has taken place near the surface, as they partake of all the characteristics of the true cements, varying only in colour, and most assuredly not being a rewash of these beds. The same remarks apply equally well to the cements of the Blue Spur and Waitahuna.

The bottom on which the cements rest is very irregular, running in at least three gutters; the yield of gold also varies greatly with the bottom; and it is worthy of note that in the alluvial workings, where gold has been got at the junction of the schists and the cements, or in the passage from a true to a false bottom, known locally as the "feather edge," the yield has frequently been very high. At Waitahuna, the cements are, to all intents and purposes, the same as those before described.

The character of the cements in the Somerset claim is very different from that of those in other parts of the field, being very brown, and the schists much decomposed. At Coombe's claim, between Adams's Flat and Waitahuna, grits occur which resemble the coal-grits as developed at Pascall's (? Cretaceous). As far as can be judged, these beds are younger than the cements themselves, [illegible]e the coal at Pascall's no doubt overlies the cements, and the grits r[illegible] into hills in the surrounding district (quartz hills) between Adams's Flat and the Tokomairiro Plains.

From Adams's Flat, the best idea can be obtained of the flow of the glacier which deposited these beds, for from here a distinct depression in the country can be seen in the direction of Waitahuna and Weatherstone's. Moreover, the character of the beds is so identical along this line as to leave no doubt in Cox's mind that the rocks constituting the cements have travelled in this direction—namely, from N.W. to S.E., and also that the means of transport has been glacier ice.

The coal formation is the one next met with in ascending order, and it is not very clear whether or no the coals of Kaitangata and Elliot Vale, of the Mount Misery coal-field, are of the same age or no as the lignites of Lovell's Flat and Pascall's, near Adams's Flat. Certain it is that these beds are separated by the Tokomairiro Plains, so that no absolute junction can be seen between them, nor can they be proved to be the same stratigraphically in this district.

It is true that a considerable difference exists between the conglomerates which cover the coal at Kaitangata, and the grits which overlie the lignite on the other side of the Plains; but this might be due to the lignites being the deposits on the sides of the basin, while the coals and conglomerates were deposited in the centre of the same.

There is another point to be taken into consideration—viz. that at Weatherstone's there are thin beds of coal below the cements or interbedded with them, and in the district of Lawrence there is a basin of lignite, as also at Evans's Flat, which is certainly unconformably younger than the cements. Cox leans to the opinion that the coals of the Mount Misery field were formed during the deposition of the cements, and that the lignites are younger than and unconformable to them, and that the grits covering these have been formed by a re-wash of the conglomerates and cements.

The auriferous Maitai slates of New Zealand are referred to Lower Carboniferous (pp. 521, 553, 570).

The Rev. W. B. Clarke also observes that one of the Nelson gold-fields, in New Zealand, is along the Waimangardha river, and that river not only rises in the Carboniferous formation (which is based on granite), but runs altogether through a coal-field; and this was reported to the Nelson Government by Clouston, in September 1862. Sections across the gold-field show no interpolation of intermediate formations. Further, Gould has reported to the Tasmanian Government that he had actually found a particle of gold in a coal-seam, and this he exhibited to the Royal Society of Tasmania. Perhaps this was set free by the decomposition of bisulphuret of iron, so common in coal, and a source of gold in older rocks.

Visible gold is found in quartz pebbles in Carboniferous conglomerate in New Brunswick (see p. 88). Gold likewise occurs in Lower Carboniferous conglomerate at Gay's river, Nova Scotia (pp. 89, 90–1). In New Mexico, it is met with in strata of quartzose sandstone probably of Carboniferous age.

Some of the quartz reefs in Ladak traverse rocks of Carboniferous age (pp. 305, 360). The gold of Minusinsk, Siberia, is partly ascribed to Carboniferous strata (p. 410). The Tertiary alluvial gold of the Tallawang field, New South Wales, has been mostly derived from coal-measure conglomerates (pp. 515–6). Traces of gold have been found in Carboniferous limestone in Somerset (p. 728).

Several groups of the Gondwana system of India (p. 305), which is considered coeval with the Permian system of Europe, are believed to contain detrital gold, especially the Talchir beds (p. 320), with probably Kamthis (pp. 323, 333, 345) and Barakars (p. 345).

JURASSIC.—The gold in the Secondary rocks of the Fitzroy Downs, and at the head of the Barcoo river, in Queensland, is referred to by Rev. W. B. Clarke as probably of Jurassic age. Belemnites and ammonites are found in the same beds with the gold-bearing quartz pebbles. Forbes, whose views concerning gold-impregnated intrusive rocks are stated in greater detail under Diorite (p. 832), and Granite (p. 834), considers the dioritic series to be nowhere earlier than the Oolitic, nor later than early Cretaceous. Deicke places the gold-veins found in chlorite-schist on the Callanda, in Graubünden, in strata of Jurassic age. He also mentions the occurrence of gold in Lias limestone at Grave, Hautes Alpes, France. The metamorphosed slates and limestones of the richest placers of Sonora, Mexico, are probably Jurassic (p. 113).

TRIASSIC.—Professor Whitney has shown that much of the gold of California is contained in rocks of Triassic age. The Triassic system forms mountain groups in Sonora, Mexico, and wherever metamorphosed is auriferous (p. 113).

CRETACEOUS.—The gold contained in the trachytes of the northern part of the Black Hills, Dakota, and in the Bear Lodge range, has been deposited in these rocks at the time of the intrusion, which Prof. Newton thinks was probably coeval with the elevation of the range at the close of the Cretaceous period.

Cox is uncertain whether a portion of the auriferous cements of Tuapeka county, New Zealand, described under Carboniferous (p. 816) are not of this age. The auriferous coal formation and propylite breccias are referred to Cretaceo-Tertiary (p. 521).

Professor Whitney declares that the greatest amount of the gold in California belongs to the altered rocks of the Cretaceous epoch.

It is doubtful whether the gold found in Secondary rocks of the Fitzroy Downs, Queensland, belongs to Cretaceous, or Jurassic, or Triassic strata.

Griesbach (Mem. Geol. Survey India, xviii. pt. i. 45–7) determines the auriferous deposits of Afghanistan (p. 270) and the Hungarian Bannat to be in Cretaceous (hippuritic) limestone, which has been transformed into finely crystalline marble by the intrusion of syenitic, granitic, and trappoid rocks, since erupted through; and metalliferous quartz veins occur along the contact-zone. The veins carry copper, lead, silver, and gold; nickel and cobalt being generally also present, and sometimes even forming the leading minerals of the auriferous area.

Forbes thinks some of the dioritic auriferous rocks (p. 832) may be as late as early Cretaceous.

TERTIARY.—The vast gravel deposits of Tertiary age, resulting from the degradation of older strata containing auriferous veins, have formed and still form the chief depository whence man has drawn his supplies of the precious metal. Many of these Tertiary deposits have yielded no fossils which would enable their date to be more accurately referred to the several periods of the Tertiary time. But as yet, none seems to have been considered of Eocene age, and few of Miocene; and the great mass would appear to be divided between the Pliocene and Pleistocene, whose relations are hitherto but little determined in the chief localities of auriferous alluvions. In addition, not a few of the igneous rocks carrying gold or influencing its occurrence are referable to Tertiary time. The most convenient subdivision of this section, therefore, will be: Miocene and Non-Miocene.

Miocene.—About ¼ mile S.E. from the gold-workings on Mayford spur, along the slope towards the Dargo, in Gippsland, Victoria (pp. 675–7), are abandoned workings, known as Synnot's claim, where several extensive excavations were made into the side of the hill, revealing a great thickness of gravel with some bands of foliated clay, in which Howitt found *Cinnamomum polymorphoides*, identified by Prof. McCoy as belonging to a fossil flora of Miocene age.

The Gippsland deposits lying between the basalt and the Silurian consist of hard silicious cement, ferruginous cement, coarse and fine gravels, clays, and occasionally impure lignites. In the report on South-Western Gippsland, it was shown that the silicious rock and cement (classed as Miocene) was older than the gravel in the lead; and the latter, on the evidence of the fossil fruit found in it, was referred to the Pliocene era, to which the leads of Ballarat are also supposed to belong. Subsequent investigations, the results of which have been published in reports on the geology of Glenmaggie, Dargo, and other parts of Gippsland, show that the silicious cement referred to is of Miocene age, and that it is somewhat older than the gravel deposits in the lead beds; it always occupies a position along the edges of the ancient channels, whose deeper portions appear to have cut through it; at the same time the difference in age is not more than the difference between the upper and lower layers of any deposit formed within a certain epoch. Both silicious rock and gravels are overlaid by basalt, which appears unquestionably to belong to the Older Volcanic period (Miocene), and this being the case, the position of the gravels as Miocene is established. In the workings of the Blue Rock (late Pioneer) claim, on the Tangil lead, where it descends below the existing river-level, are found fossil fruits, among which Baron Von Mueller identified *Spondylostrobus Smythii*, *Phymatocaryon Mackayi*, *Celyphina McCoyi*, *Conchotheca turgida*, and *Platycoila Sullivani*—all identical with those found in the leads of the Ballarat district. On this evidence, the Tangil lead gravel was, in the previous report, referred to the same age as the Ballarat leads, and its overlying basalt to the Newer Volcanic period. There is, however, no evidence to show that Miocene flora may not have continued to flourish into the Pliocene epoch; and though the leads of Ballarat and Tangil be of different ages, the vestiges of similar flora may be discovered in them. It is very probable that the outlines of all the main drainage courses of the Tertiary period, whether Miocene or Pliocene, were formed early in the former epoch. As regards the auriferous character of the Miocene gravels, the only place where they have been worked, or even prospected, is where a section of the old lead—cut through at either end by, and included within a large bend of, the existing river—remains about 1 mile S. of the Tangil township. The gravels beneath the basalt were here easily detected and their quality tested. The greatest thickness of the Victorian beds of Miocene age is probably more than 600 ft.

Professor Judd concludes his remarks on the ancient volcano of Schemnitz, Hungary, by saying that the "mineral veins of Hungary and Transylvania, with their rich deposits of gold and silver, cannot be of older date than the Miocene, while some of them are certainly more recent than the Pliocene. Hence these deposits of ore must all have been formed at a later period than the clays and sands on which London stands; while in some cases they appear to be of even younger date than the gravelly beds of our Crags!"

Gold is found in the Miocene metamorphosed rocks in Costa Rica (p. 98). Miocene is stated by some authorities to be the age of the mineralization of the Ruby Hill ore deposits, Comstock lode, &c. (p. 176). The auriferous Ross beds of New Zealand are referred to Lower Miocene (p. 521). Some of the Ballarat leads are considered to be Miocene (pp. 659–60).

Non-Miocene.—It is considered certain by others that the whole series of volcanic outbursts in the Comstock lode rocks are since the Miocene epoch.

The alluvial leads of India (pp. 306, 343, 344, 345, 347) are found in Siwalik (Pliocene) beds.

The Desert Sandstone of Queensland has not yet afforded fossils enabling its age to be fixed. What may be its value for free gold is at present unsolved, but Daintree thinks the nature of its deposition seems to preclude the idea that the metal will be found in paying quantities, except where direct local abrasion of a rich auriferous vein-stone has furnished the supply.

The Geological Survey Reports of Victoria divide the auriferous into older drifts [Middle Pliocene] and oldest drifts [Lower Pliocene]. The former are in many places covered by sheets of volcanic lava. Fossil fruits, some of a coniferous genus, allied to *Cupressinites* of Bowerbank, are abundant in the clays overlying drifts in Victoria, New South Wales, and Queensland. These drifts are found at depths varying from 50 to 400 ft. The so-called oldest drifts of Victoria are considered undoubtedly of marine origin. Silurian bed-rock, resembling that of a rocky seashore, and masses of quartz (some 4 ft. by 5 ft.), well rounded, and large boulders, together with drift, much water-worn, constitute the auriferous stratum. The gold is in many places distributed through 20 ft. or more of drift. The observed thickness of this drift is 25 to 35 ft. where much eroded, probably reaching 100 ft. elsewhere.

Ulrich classes the Victorian gold-drifts under three heads, and describes them as follows :—

"I. The Older Pliocene or Lower Gold-drift.

"The special character of this drift is that its gravelly portion is principally composed of quartz pebbles or boulders, which, as well as the gold contained in it, are perfectly rounded or water-worn. Although it is in some places—as, for instance, in the White Hills at Bendigo, the Loddon valley hills, &c.—well arranged according to size—i. e. from small to large, from the top downward—still it is more frequently observed that though the coarsest—the real boulder-drift—lies at the bottom, the superincumbent portion is variously composed in different localities. In our western gold-fields—Ballarat, Castlemaine, Avoca, &c. —it consists of layers of sand and clay, of sandy and clayey, coarse and fine gravel, and where filling deep valleys and carrying the present surface drainage channels, beds of real drift-sand are not unfrequent. In the large deposits of this drift discovered on the Tangil river, Gippsland, the pebble drift, or rounded quartz-gravel, is only a few ft. thick, but covered in places by over 100 ft. in thickness of an indurated, yellow or brown, very arenaceous clay, which so closely resembles the soft, yellow, Silurian sandstone—the rock-bottom of the district—that, except for its horizontal bedding, and the absence in it of small quartz-veins that are always present in the true bottom-rock, it might be easily mistaken for the latter.

"The predominating colours of this drift are either white or brown, or white and brown mottled, whilst the bottom layer or wash-dirt is often rich in a black carbonaceous clay, or shows a covering of this clay, in which remnants of trees—as branches, roots, trunks, leaves, seed-vessels, &c., all more or less carbonized, or sometimes wholly or partially converted into iron-pyrites—are often found enclosed. In some places, beds of real lignite, or brown coal, have also been found above the wash-dirt. Layers of hard ferruginous conglomerate, from a few in. to several ft. in thickness, and requiring blasting operations in working, are hardly ever absent, especially near the bottom of the deposit; and a peculiar, extremely hard and dense silicious cement—a real quartzite—is sometimes observed in cakes near and at the top along basalt escarpments, or where the drift deposit is exposed near basalt-flows. The fact that these cement cakes, which are often many ft. thick, do not extend beneath the basalt, but occur only where the drift was exposed to the atmosphere through denudation of the basalt, would tend to indicate that they are, as it were, the products of local metamorphism of sandy clay or sand, in which silicious waters, produced through the denudation of the basalt, in connection with atmospheric agencies, performed important parts. Touching the mode of occurrence of the drift it is twofold:—

"(*a*) *As Hills*, either solitary or in series, more or less connected, bounding gullies and flats, or more rarely rising in the centre of flats —as, for instance, the White Hills, Maryborough, a hill in the Loddon river flat below Guildford, &c. Where these hills are covered by basalt, they are generally of far larger size than where exposed (Loddon valley outliers, &c.), which is owing to the protection against denudation afforded by this rock to the drift: for the mode of occurrence of the latter as hills is plainly a result of denudation, the deposit having once filled old valleys in unbroken streams; but whilst first being indirectly raised through the formation of new valleys alongside, it was in aftertimes laterally cut into, and thus divided into parts (the present hills) by small gullies (the present drainage channels). The rock-bottom of these hills lies, in the higher parts of the gold-fields, generally high above the surface of the flats and gullies; but it is frequently the case that, towards the lower parts, it gradually sinks lower and lower, and not only disappears beneath the surface of the flats, but runs at last actually far lower than the rock-bottom of the latter above and below its limits, thereby proving conclusively that the old valleys had a steeper fall than the present ones. As regards the character of their mass, hills contain nearly always (and frequently strong) layers of conglomerate, whilst soft clay and sand-beds are less common.

"(*b*) *As so-called Deep Leads.*—In this case, the drift fills deep valleys and channels, which carry the present surface drainage, a mode of occurrence well exemplified at Ballarat, Bagshot, near Sandhurst, Eldorado, Beechworth, &c. The term 'lead' was originally intended only for the continuous run of paying washing-stuff, occupying mostly the deepest part of the channel, the so-called 'gutter'; but it is now generally applied not only to the whole extent of this kind of deposit and to series of connected hills, but also to similar hills and drift channels of the Newer Pliocene, next to be considered. As will have been gleaned from the description of the hill deposits, the genuine Older Pliocene deep leads are continuations of the latter, and, to attach a stricter meaning geologically to the term 'deep lead,' they ought to be considered to commence where the top of the deposit becomes level with the adjoining flats or gullies, whilst its rock-bottom runs at a lower level than that of the latter, or, where the deposit enters the flats, and becomes overlaid by more recent gold drifts. The deep leads are divided into main-trunk leads, main leads, main-branch leads, branch leads, according to their topographical relations to each other. At Ballarat, for instance, several strong basaltic flows cover extensive old watersheds, comprising a great number of branch leads, joining main-branch leads, which unite to several main leads, and these ultimately to the main-trunk leads. The line of drainage of the deep leads does not generally agree with, and is in some cases quite the reverse of, that of the present surface. A fine instance of this is observable close to Malmsbury. The old Belltopper lead runs there across the present Back Creek, and joins the old Coliban river lead close to the township, not far from the point where the old Taradale leads also join the old river lead, which latter runs from there right across the present Coliban river valley in the direction of the valley of the river Campaspe. This peculiar relation is easily understood from the geological features of the district; namely, whilst the extensive basaltic stream that covers the drift of the old valleys appears at gradually increasing heights above the present Coliban river-bed in the upper part of its course, it forms below Malmsbury the bed of the river itself, which consequently proves that the drift must lie at a considerable depth beneath the river. But as there is no evidence lower down the latter of any such deep outlet, and as, besides, the Taradale leads run S., whilst it runs N., the only conclusion we can come to is that the old river channel—the main lead—trends E. towards the Green Hill, in which direction it must join the old valley of the Campaspe river.

"The discovery of the payably auriferous portions of deep leads gutter or rise, as the case may be, is, especially in wide extensive valleys covered by basalt, a matter of great difficulty and expense, and can only be accomplished in an economic manner by systematic boring operations, as already introduced at Ballarat, Beechworth, and other gold-fields. There are many places in the western gold-districts where extensive deep leads do no doubt exist, and prospecting by boring would be highly advisable. A most promising one is the large tract of basalt country bounded by the Clunes, Carisbrook, Hepburn, Glengower, &c., gold-fields, and called, beyond Joyce's Creek, the Bay of Biscay. All the old drainage channels of the area must, according to the topographical and geological features, join the old Loddon river; and as the basalt-covered valley of the latter is in the neighbourhood of Eddington hardly a mile in width, this locality is no doubt the most favourable one for prospecting the old main-trunk lead. A bore was in fact commenced here some years ago, but the breaking of the boring-rods caused it to be abandoned before it had reached the rock-bottom.

"II. The Newer Pliocene, or Middle Gold-drift.

"This drift is generally not so extensively developed as the other gold-drifts, though it is doubtful whether what are on some gold-fields considered as the older deep leads, may not, in reality, belong to it as regards geological age, a point to be noticed further on. It occurs, like the older gold-drift, both as hills and deep leads, and its connection with that drift is very various. For instance, where both drifts occur as hills, the older drift lies sometimes considerably higher—as, for instance, at Fryer's Creek, Sailor's Flat, near Vaughan, &c.; or, as at Forest Creek and Barker's Creek, they lie side by side, either quite separate or the younger overlapping the older; or, as at Maldon, where the middle drift covers the older. At some gold-fields, the older drift forms hills alongside of or within flats that contain channels or leads of the middle gold-drift, covered by the upper gold-drift—for instance, at Talbot, Maryborough, Sandy Creek, near Maldon, &c. The rarest case is of both drifts occurring as deep leads in flats, the older drift resting on the bottom, being overlaid by the middle drift, and this again covered by the upper gold-drift. An instance of this exists in the lower part of Sandy Creek flat, near Newstead.

"Touching the character of its mass, the middle gold-drift differs from the older drift by the imperfectly rounded state of its quartz-pebbles and gold-particles, by a considerable admixture of Silurian rock-pebbles, and by striking colours, such as red, blue, greenish-yellow, &c., often all shades, marble-like mottled. Its mode of arrangement from top to bottom is rarely also as perfect according to size as is the case with the older drift. Where occurring as deep leads, it frequently contains layers of carbonaceous clay, full of fragments of wood and plant impressions; yet the wood is not nearly so carbonized as that of the older drift. So-called cement or conglomerate layers occur also frequently, more especially in hill deposits; their character is different, however, from that of the puddingstone of the older drift, being more that of a 'breccia,' whilst the cementing medium is hardly ever hydrous oxide of iron (brown iron-ore) in a pure state, but generally consists of a small percentage of it permeated through silicate of alumina, i. e. of indurated ferruginous clay. In some cases it is also calcareous, or consists of pure carbonate of lime, as, for instance, in some parts of the Sandy Creek lead, near Maldon.

"As regards the supposition previously advanced, that some of the deep leads classed under the older drift might, as regards geological age, belong to this middle gold-drift, the deep lead of Epsom Flat, near Sandhurst, and some of the Ballarat leads, may be instanced. The White Hills of the former locality belong undoubtedly to the older drift, consisting nearly throughout—the seventh White Hill, for example—of above 60 ft. of more or less cemented, perfectly water-worn gravel, arranged tolerably well, according to size, from fine gravel at the top to large boulders at the bottom. On the N. base of this White Hill, the Epsom lead, covered by upper gold-drift, commences; but it contains only a few ft. of cemented, rounded quartz-gravel and boulder-drift at the bottom, the remainder consisting of white or variously-coloured arenaceous clay layers, which have no regular connection with the seventh White Hill gravel; whilst, moreover, the bottom of the lead lies considerably lower than that of the White Hill. Considering these features in connection with the occurrence of small patches of genuine older drift conglomerate on the rises bounding Epsom Flat, it seems very probable that the deep lead channel is, in its upper part at least, of later formation than the hills, having been washed out in an apparently wide expanse of the older drift, and partly filled with re-washed material of the latter. At Ballarat the discovery has been made in later years that there exists a 'high-rise' gravel along some of the deep gutters, which latter are mostly filled with clay and drift sand, and but a few ft. of boulder-wash at the bottom, evidently analogous features and relations to those just described of and between the White Hills and Epsom lead. Similar occurrences obtain probably also at other gold-fields. Touching the determination of the exact boundaries between the two drifts in cases like the Epsom Flat lead, it is quite impossible, on account of the never-absent covering of upper gold-drift and the great similarity in the material. This does not, however, affect the miner, for to him the distinction between the two drifts has little practical value.

"III. The Post-Pliocene, or Upper Gold-drift.

"Under this head are comprised three different deposits, viz.: (*a*) the Alluvial-drift, or simply 'Alluvial,' as the digger calls it; (*b*) Recent River-drift; and (*c*) Surface.

"(*a*) *The Alluvial drift* fills every flat and gully throughout the gold-fields, and is covered by soil and vegetation. It is generally composed of alternating layers of tough brown or bluish clays, indurated, ferruginous sands, and clayey gravel, which latter is mostly coarsest at the bottom, representing the 'washing-stuff,' and consists of a mixture of angular, or but very slightly rounded fragments and pebbles of quartz and all kinds of rocks, derived from the bounding rises and ranges of the flats and gullies. Sometimes it shows only 1 or 2 ft of tough, sandy ferruginous clay at the top, and the remainder is formed throughout of clayey gravel, which only becomes somewhat coarser towards the bottom. Again, there are gullies showing from less than 1 to several ft. of auriferous gravel at the bottom, covered by a far greater thickness of tough and sandy clays in alternating layers. As regards its thickness, it varies from a few to above 60 ft. in different localities. In the lower parts of gullies and flats it is always the thickest, thinning out towards the commencement of the gullies in the ranges. The gold it contains is generally but little water-worn; only in those gullies that separate the older or the middle drifts into series of hills occur often rich deposits of water-worn gold, in a gravel composed of more rounded quartz and rock-pebbles, evidently the remnants of the denuded older drifts. Touching the position of this drift, if in contact with the older drifts, it covers them without exception where they form deep leads and no basalt intervenes. As in cases of this kind the probability of the existence of two payable wash-dirt layers is given—namely, of one immediately resting on the older drift—the so-called 'false bottom'; of the other lying on the true rock-bottom—careful prospecting of the upper floor is highly advisable.

"(*b*) *Recent River-drift*, as the name implies, consists of the occasional, generally patchy accumulations by floods of shingle, sand, and clay along the courses of creeks and rivers, and is but rarely payably auriferous. It rests on the creek and river banks upon the soil covering the upper gold-drift; and, if happening to escape denudation by recurring floods, it may in course of time become also covered by a thin layer of soil and vegetation. This explains what is not unfrequently found in some river flats (Coliban, Ovens, Loddon rivers, &c.), viz. of two or more shingly or sandy beds, with thin layers of old humus or former surface soil intervening, having to be sunk through before the genuine clayey alluvial gold-drift is reached. To this recent drift belongs also the shingly material occupying the old watercourses that generally traverse most flats and wide gullies. Filling these old channels in most cases right up level with their banks, and being covered by soil and vegetation, this drift is seldom recognisable at the surface; and as it sometimes extends right down to the rock bottom, the miner working a claim on it has but a poor prospect for gold, though claims close adjoining, outside the old watercourse, may prove very rich. In deposits of this drift, broken and perfect shells of the common *Unio* are frequent, and so are trunks and other remnants of trees of the kinds lining the banks of the rivers and watercourses.

"(*c*). *Surface* deposit, which derives its name from its occurrence right at the top of the ground, is the most far-spread of our gold-drifts. Being a result of the disintegration of the Silurian rocks *in situ*, and, owing to the general softness of the latter, it covers nearly every hill and range of these rocks, though being—with one exception, to be mentioned farther on—only payably auriferous in the neighbourhood of auriferous quartz reefs. Its thickness varies from a few in. to above 1 or 2 ft., according to the less or more decomposable nature of the underlying rocks; and it consists generally of clayey and sandy matter, mixed with angular fragments of quartz, sandstone, and slate, and carrying some humus supporting vegetation. The gold it contains is quite angular, hackly or crystalline, and is derived from auriferous quartz reefs or leaders existing in the immediate vicinity. For this reason it affords, by prospecting and washing, the best guide in the search for such reefs. Whilst the auriferous character of the Older and Newer Pliocene drifts offers only a general certainty, as it were, of the existence of gold-bearing reefs in a district, gullies filled with auriferous alluvial, especially their upper portions, afford undoubted proofs that auriferous reefs occur in the neighbouring hills and ranges ; but only the prospecting of the surface on the slopes of these hills and ranges will in most cases actually lead to the discovery of the reefs themselves. The exception previously spoken of comes here, however, under consideration. It refers to auriferous surface composed of disturbed Older and Newer Pliocene drift—in fact, remnants of imperfect denudation of these deposits—always betraying its character by the very waterworn condition of the gold it contains, and generally, though not always, by smooth rounded quartz pebbles. It occurs mostly on the slopes of and in the gaps between the hills, the tops of which carry patches of the older drifts ; sometimes, however, any undisturbed remains of the latter may be entirely absent in the immediate vicinity. Such surface has been worked in many parts of Maldon, Fryer's Creek, Campbell's Creek, and other districts ; and the misunderstanding of its true nature has led to frequent vain attempts to discover in the neighbourhood the quartz reefs its contained gold was supposed to be derived from.

"With regard to the comparative richness in gold of the different drift deposits just described, it may be affirmed that, comparing different areas, the Older Pliocene drift is the richest ; but, on taking the entire extent of each of the drifts into calculation, it seems indeed very probable that the alluvial drift, as the more extensively developed, furnishes more gold than any of the other deposits.

"The site of the richer washing-stuff in the course of the leads and alluvial gullies and flats is, according to experience, connected with certain features of the rock bottom and surrounding country. As some of the rules deducible in this respect may be mentioned the following: Rich wash-stuff occurs—(1) Where the bottom suddenly assumes a flatter inclination or fall than it had previously. (2) Generally in the upper or commencing parts of the deposits, for the lower downward in the channels, the slower and broader the original current, the finer and more scattered the gold particles, more especially if, as it frequently happens, there are junctions of branch leads and gullies that only furnish an accession of poor or barren material. (3) At such points where the current of the water was, through some local impediment, intercepted or dammed up, suffering thereby a retardation of its velocity, and permitting in consequence a deposition of the heavier particles previously carried along—for instance both in front of and beyond narrow places in the channels, and where the latter make sharp bends. It happens, in bends especially, often that the gold, on account of the break in the current, is found thrown high up on the opposing rise, whilst in straight portions of the channels it lies more in the deepest parts or 'gutters.' Where bars or rises of the bottom rock traverse gutters, it is not unfrequently found that the richest, though generally thinnest, wash-stuff rests right on top of the bars or rises, and that the slope of the latter facing the current carries lower and poorer wash-stuff than the opposite one. (4) Rich wash-stuff may always be expected at the junctions of two or more leads or gullies, each of which is payably auriferous by itself. (5) Where auriferous quartz reefs traverse leads and alluvial gullies, either laterally or longitudinally. In the first case, the greater richness of the wash-stuff extends generally only for some limited distance below the reefs; but whilst the extent is greater if the angle of traverse is acute, the most favourable result is produced in the second case, where the reefs run actually in the channels of the drift deposits. Much depends in these respects, of course, upon the thickness and quality of the reefs, the fall of the channels, &c. (6) In the cracks and pits ('dips,' in miners' phrase) of an uneven bottom, the gold having there found a resting-place protected against the currents of the water. On this account it is also often observed that those portions of alluvial gullies and leads that run across or at right angles to the strike of the bottom rocks, especially where these are rather hard and jointed, and therefore expose the serrated edges of the beds, are richer, or contain frequently at least richer patches, than where the drift deposits run with the rocks. As a general rule, drift miners prefer, however, a soft bottom to a hard one.

"Various other conditions and circumstances connected with the deposition of rich wash-stuff might be mentioned, but a consideration of all leads to the general conclusion that such deposits are very irregular, and, both as regards superficial extent and thickness, subject to frequently very sudden changes. At one place it forms stripes, at another, irregular nests and patches, whilst its thickness may decrease from several ft. to hardly as many in.; sometimes it is sharply defined, and abruptly terminating; sometimes without any distinct boundary, and gradually running out all round."

Whitney's opinion of the high gravels of the Sierra Nevada of California is that they are the work of rivers of Tertiary age. That volcanic agencies have played an important part during the gravel epoch, and especially towards its close, is also perfectly clear, the heavy covering of lava over the gravels acting as a mechanical protection to that which is beneath. It may be set down, too, as established beyond any possibility of doubt, that ice had nothing to do with any part of the erosion of the gravel period. Different conditions prevail in different portions of the range with reference to the development of the volcanic formation and gravel. The portion S. from Mariposa contains hardly any rocks which can properly be called slaty, and has never been found sufficiently auriferous to make either surface or vein mining profitable. The distinguished "red" and "blue" gravels have been shown to be one, the former being merely the result of oxidation of the latter. The gold is almost exclusively limited to the quartz and metamorphic gravel. It is a general rule, with only rare exceptions, that in a given bank the richest portion of the gravel, as well as that containing the coarsest gold, lies immediately on the surface of the bed-rock. Whitney believes that this is correctly explained by the hypothesis that neither the coarsest gold nor the largest boulders were ever transported very far from the spots whence they were originally derived. On the other hand, it is an invariable rule that the coarser the gold the less is its market value, by reason of the greater proportion of silver in the native alloy.

IGNEOUS.—*Diorite.*—In the mining districts of Transylvania and Hungary occur volcanic rocks of compact porphyritic or crystalline-granular structure, and composed of plagioclase felspar, together with hornblende or with mica, and often with quartz. They have been variously described, both as to character and geological age, but are now "recognized as hornblende or mica andesites, or quartz-andesites [dacites]. They resemble in a remarkable manner the porphyrites, the diorites, and the quartz-diorites of pre-Tertiary age."

According to one authority, the Comstock lode is in andesite. Mount Davidson acted as a most powerful agent "in determining the position and character of the Comstock lode. . . . No place offers such conditions of easy fracture as the contact-plane between the ancient and deeply-bedded formations, and those later and less coherent eruptive rocks which have been superimposed upon their bases. Accordingly along this important junction occur the relics of a dyke of andesite, which seems to have been the first foreign substance to invade the contact-plane and start the system of intruded materials which has finally resulted in the Comstock lode."

Wilkinson notices in some of the New South Wales gold-fields that hornblendic granites and intrusive greenstone or diorite are the original source whence the gold found in the alluvial deposits has been derived. At Grenfell this is very marked, a large mass of porphyrite intruding Upper Silurian schists. Quartz reefs, varying in thickness from that of a mere thread to over 10 ft., traverse the intrusive rock in a N.E. direction, and in some instances pass into the adjoining schists; but though richly auriferous while in the former rocks, they cease to be so immediately on entering the schists.

At Gympie, D'Oyly Aplin has shown that the reefs are closely associated with greenstone dykes, and that where these do not occur, the drifts are comparatively barren.

Many of the reefs at Swift's Creek, Victoria, are situated (1) in the line of contact between intrusive masses of diorite and sedimentary rocks, and (2) in the regionally metamorphosed Silurian beyond the contact. The former penetrate through the contact into the underlying quartz-diorites; they have been found to be the richest near the surface, to dwindle away as they penetrate deeper, and to become less auriferous or cease at no great depth from the surface. It may, perhaps, be of some significance that, where the reefs discontinue, the dioritic rocks, as a rule, cease to be decomposed. Some few auriferous reefs have been discovered and worked within the diorite area; but in these cases, isolated patches of contact schists associated with them prove that the general absence of these rocks is in reality only due to denudation.

Among the modes of occurrence of gold in E. Australia, Daintree mentions pyritous diorites, as at the Gooroomjam diggings, Queensland; alluvial drifts from these contain gold in paying quantity.

The second appearance of gold in S. America, according to Forbes, is totally distinct from the first (see p. 835) in mineral character, as well as in geological age, and results from the eruption of dioritic (greenstone) rocks, composed of hornblende and felspar (without quartz), which break through strata even as late as those containing Oolitic fossils, and consequently must be regarded as younger than the Oolitic period, but as far as researches have yet shown, are probably not posterior to the deposition of the Cretaceous strata. In this case, instead of quartz-veins carrying the gold from the granite into the neighbouring strata, veins of metallic sulphides and arsenides act in the same manner, and the gold is found imbedded in its metallic state in the compounds of sulphur and arsenic with iron, copper, &c.; and from some unknown cause the more superficial parts of these veins appear as a rule to be much richer in gold, which by the miners is generally supposed to decrease in depth. The minerals commonly found in these veins are not the same as in the metallic veins mentioned as occurring with the granitic rocks under the first head, and, as far as observations have gone, the metals, tin, tellurium, tungsten, titanium, selenium, &c., are never found in the auriferous veins of later dates. Nothing could be more conclusive than the totally distinct age of these two sets of auriferous eruptive rocks, which Forbes believes to represent the only ages at which gold has been introduced into the upper crust of the globe, and thinks it probable that this generalization may be carried into other parts of the world, if it be not altogether universal.

In his later extension of his theories to all the gold-deposits of the world, as stated under "Granite" (p. 835), Forbes deals with dioritic gold in the following terms :—

"The newer, or dioritic, outburst I have called Post-Oolitic, as the veins containing gold, and which proceed from its centres, cut through strata containing fossils of decided Post-Oolitic forms, and possibly may be as late as early Cretaceous. These strata are frequently much altered and metamorphosed by the contact of the igneous diorite, and at such points often become auriferous, or are cut by auriferous veins proceeding from the diorite head mass. Although the results of an extended examination of these deposits in Chili, Bolivia, and Peru, occupying me from 1857 to 1863, are extremely interesting, I have only had time to publish comparatively few of the observations made. Since my return to Europe, however, I have been able to collect sufficient data to show me that this occurrence of gold is not at all confined to South America, as I had at first imagined, but appears also to be common to all the other quarters of the world. I have seen auriferous diorites from Italy, and some auriferous rocks of this class are known to occur in the Ural; and, as before mentioned, I have specimens from California, and some time back received very similar specimens, through Lieut. Aytoun, from the gold districts of India; and lastly, within a very few days, I have had the opportunity of examining a fine series sent over to the Jermyn Street Museum by Mr. Aveline, the head of the Geological Survey in Victoria, which are all strikingly similar to those examined by myself in various parts of South America."

Professor Judd, when describing the ancient volcano of the district of Schemnitz, Hungary, says that "in every instance" of the centres of igneous activity in Hungary and Transylvania, "we find proofs that the more deeply-seated masses of andesitic lava have, in consolidating, assumed a highly porphyritic or granitiform structure, and that the action upon these of acid gases and vapours has resulted in the decomposition of the mass, with the diffusion of valuable metallic ores throughout the substance of the rock, and their accumulation in considerable quantities wherever a suitable fissure occurred in it." And he concludes with a remark that there is the most complete and insensible transition from the granitic rocks to the true lavas; "and the whole of them are of Miocene date."

Diorite is the country-rock of some of the chief gold veins of Venezuela (p. 267). Gold is found in the disintegrated diorites of Khutel, Turkestan (p. 473). The placer-gold of the Urals, according to Murchison, lies chiefly on a greenstone bed-rock (p. 427). Greenstone or diorite is the main source of much of the gold of New Guinea and New South Wales. At Temora, gold is found in the reefs traversing diorite, but not in those in the slate (p. 516). Some of the reefs on the Thames gold-field, New Zealand, are in diorite (p. 553). Dioritic dykes accompany many of the Ballarat (p. 673), Gippsland (pp. 682, 684), and Western Australian (p. 696) veins.

Granite.—The lodes around Central City, Gilpin county, Colorado, are said to be all enclosed in rock which is of one common type, chiefly granitic, with some gneissic varieties. Gold has been found in true granite, closely resembling the variety called protogine, abundant in some parts of the Alps, at Sandy Creek, Victoria. Some of the specimens are very rich, and would assay several oz. per ton.

D'Oyly Aplin, in 1864, reported on the occurrence of auriferous quartz veins, varying in thickness from a few in. to several ft., at Wood's Point, Upper Goulbourn, Victoria, traversing in a more or less horizontal direction, and at different levels, a rock of granitoid, or rather syenitic, character, but which, existing as a broad dyke with well-defined walls, differs essentially, as a geological feature, from granite in its ordinary position as a rock mass. The rock constituting the dyke is a mixture of hornblende and felspar, with but little quartz, and occasionally mica, and might perhaps more correctly be called syenitic diorite. Crossing the dyke at different levels, some 60 or 70 ft. apart, are 3 horizontal bands or veins of quartz, more or less undulating in their course, and varying in thickness from 1 to 12 ft. As they approach the walls of the dyke, they exhibit a tendency to split up and become attenuated, but become exceedingly rich on entering the slates.

Interesting and apparently valuable discoveries of metalliferous lodes in granitic rocks have been made at Bethanga, E. of the junction of the Mitta-Mitta with the Murray river, Victoria. The veins are of exceptional character in Victoria, inasmuch as they contain in quantity the 3 metals, gold, silver, and copper, but they closely resemble some auriferous veins found in Queensland. The walls of the lodes are well defined. The yield of the stuff has averaged over 1 oz. per ton, the vein being 2 to 7 ft. wide. The stuff is a ferruginous gossan containing gold, silver, and copper, distributed through the ore without any apparent order.

Morton says of the gold-bearing veins of the Virginia Gold Belt that they are generally of two classes:—(1) Veins in the slate, striking N.E. and S.W.; (2) veins in the syenite, striking S.E. and N.W. approximately, the larger veins occurring in the syenite. The characters of the veins differ in this: that in the syenite they are more persistent in length, and dip at a nearly vertical angle, while in the slate they are more irregular in length, and dip at various angles, from 25° to 80° from the horizon. The characters of the ore also differ, inasmuch as in the slate the quartz is more laminated than in the syenite, and the quantity of free gold is greater than in ores of equal assay value from the syenite.

At Kaffir's Hill, Stockyard Creek, Victoria, auriferous quartz-veins occur in a granitic dyke, and extend into the slate country on either side, which is also, together with the quartz, much impregnated by iron-pyrites.

Among the modes of occurrence of gold in Eastern Australia, Daintree specifies the granite of Bowenfels and Hartley, New South Wales.

David Forbes, F.R.S., after 7 years' study of the gold deposits of S. America, classes them in two categories. "Under the first head belongs all gold derived from the disintegration of granitic rocks of an age later than much, if not all, of the Silurian strata, but probably not later than the Devonian period. The largest gold-washings of S. America, and probably of the whole world, I look upon as derived from this source, as well as the auriferous quartz-veins, as they can be traced to the proximity of the granite, and which I believe to have originated in or been injected from the granite into the neighbouring strata, carrying the gold, which is a normal constituent of the granite itself, along with it. This granite, wherever met with, is invariably auriferous in itself; and although it would not pay to grind down granite mountains, and work out the gold in them, yet in many parts of S. America, in Brazil, near Valparaiso, &c., the granite, apparently solid, is frequently decomposed *in situ* to depths of even over 200 ft., as shown frequently in railway cuttings, and then it sometimes repays the labour of washing the whole mass for the sake of the gold in it. To this class also belong many metallic veins injected from the granite into the neighbouring Silurian strata, which contain gold, and are remarkable for the presence of other minerals, very characteristic, as oxide and sulphides of tin, tin-pyrites, copper-pyrites, compounds of bismuth, tellurium, selenium, &c., many of which are seldom or never met with in later rocks."

Subsequently Forbes extended his conclusions so far as to enunciate two epochs of auriferous impregnation throughout the whole world: (1) the older or granite outburst, and (2) the younger or diorite (see p. 832) outburst. Concerning the former he says as follows: "The older or auriferous granite intrusion appears to have occurred at some time between the Silurian and Carboniferous period, certainly not older than the Upper Silurian, nor younger than the Carboniferous strata, probably not younger than the deposition of the first members of the latter formation.

"Gold formations belonging to this period present themselves in Australia,* Bohemia, Bolivia,* Brazil, Buenos Ayres, Chili,* Cornwall, Ecuador, Hungary, Mexico,* New Granada, Norway, Peru,* Sweden, Ural,* Wicklow.

NOTE.—These so (*) marked, as well, I believe, as California and many others, have gold deposits of both ages.

"To this period and cause I also attribute most of such deposits of gold as are found intruded as quartz nodules and veins in many places, as if interstratified in the Cambrian and Silurian (and probably also Laurentian and Devonian) systems, which I believe to have arisen and been rendered auriferous solely from their proximity to invisible or now superficial granites."

Speaking of the celebrated Nuggety reef, Maldon, Victoria, Ulrich says, "the granite of all the veins, and that of the bottom floor, differs but slightly in universal character from the main mass of the rock in the immediate neighbourhood (it appears in the veins to be perhaps somewhat more quartzose, and to contain less mica), and there can hardly be a doubt that the second and third veins were once connected with the main mass, whilst the remainder and the bottom floor are still so, and may lead up to it if followed northward. Yet the assumption of, especially, the first 3 veins being intrusive is strangely at variance, touching their mineral connection with the reef, for there is a complete absence of any division-line between the quartz and granite—a feature generally observable between intrusive dykes and the surrounding rock. The granite appears here, in fact, not at all unlike a zone of impregnation, inasmuch as the quartz above the veins shows, first, scattered crystals and pieces of felspar; these increase gradually in quantity; plates and nests of black mica make their appearance, and, whilst their number also augments, the mixture becomes more and more fine-grained, and the passage to typical granite is insensibly completed; the reverse process of change to reef-quartz commencing again a few ft. below. Even the gold takes part in the passage, for it has been found impregnated several in. deep in the granite."

At Beresof, 10 miles N.E. of Ekaterinburg, gold-quartz veins occur in dykes of very fine-grained granite, called beresite. The celebrated auriferous mispickel veins of Marmora, Ontario, Canada (see p. 79), are true fissures in syenitic granite, with micaceous or talcoid slates forming the walls of and horses in the veins.

Granite is associated with the gold-mines on Jackfish and Partridge Lakes, Canada (pp. 79-80). On ascending the Saskatchewan, the gold declines with the disappearance of granitic and gneissic rocks (p. 81). Some of the auriferous veins in S. Carolina are in coarse crystallized granite. In the Ili basin, Turkestan, gold is only found in the affluents which issue from syenitic granite spurs; in the waters abrading the schistose rocks, there is no gold (p. 473). The Serdjiller gold-mine, Asia Minor, is in syenite and mica-schist (p. 475). The gold-reefs at Poverty Point, Clarence district, New South Wales, are in granitic dykes (p. 487). The shallow Four-mile diggings, in the Kiandra district, have a granitic bed-rock (p. 506). A granitic dyke has yielded the gold of the deep leads of the Lachlan district (pp. 512–3). The Charters Towers gold-field, Queensland, occupies the edge of an area of granite and syenite (p. 585). The Black Snake gold-workings are in granite (p. 591). Granite and syenite form the country-rock in the Marengo gold-field (pp. 593, 595, 596, 610, 611, 612). Granite is the bed-rock of some of the Victorian leads, and country-rock of some of the veins (pp. 651, 652, 653, 654, 656, 682).

Porphyry.—White states that the "Bolivia" lodes, in the Frontino and Bolivia Co.'s mines, in the United States of Colombia, are "in first-class metalliferous porphyry."

Daintree describes the occurrence of gold in porphyry at Paddy's and Sharper's Gullies, on the Cape River gold-field, Queensland. These gullies are short ravines joining the main creek about 3 miles above the junction of Running Creek and Specimen Gully. The shallow alluvial deposits in these watercourses were very rich; the material composing the drift was entirely made up of fragments of decomposed felstone-porphyry, and the rock-mass through which they had cut their channels was the solid representative of the débris in the gullies. The surface rubble on the hill-side near the head of Sharper's Gully, which is simply broken-up felstone-porphyry, was sluiced with remunerative results. The gold is of the class called by miners "dirty" or "black" gold. In the one case, it is encased in material similar to the wash-dirt from which it is separated; in the other, the coating is manganic oxide of iron, similar to the black gold of Canoona. As no portions of either of these gullies traverse the rock, and as none of the gold has quartz attached, or shows signs of having been transported from a distance, and as, whenever it is collected with adhering particles of matrix, they are invariably similar to the rock-mass which bounds the ravines, the gold has clearly been derived from the destruction of the felstone-porphyry, which here forms the bottom-rock of the miner, as its disintegrated particles make up his wash-dirt.

At another place, great care was taken in tracing the course of a peculiar porphyritic dyke, and it was found that wherever it traversed the slates on its extension, as it does where it crosses Golden Gully, near the "Dam," there the richest gold-deposits were found. A patch of surface ground was worked at the head of a right-hand branch of Golden Gully, with "wash-dirt" and gold both similar to those in Paddy's Gully, and there can be little doubt that the red clay soil at the head of Nuggety Gully indicates the presence of this peculiar feature, and suggests the origin of its alluvial wealth. That these porphyritic elvan courses have influenced the local production of gold in the area under discussion, is further evidenced by the fact that none of the gullies between Nuggety and Specimen have been gold-producers, though the mica-slates through which they force their way differ in no respects from those worked to a profit than in the absence of these same intrusive dykes. Again, if these have not played the important part here assigned them, how shall the comparative barrenness in mineral be accounted for in the extension to the N.W. of the same schistose rocks?

Porphyritic dykes are the source of the alluvial gold in Borneo (p. 290). Some of the veins on the Thames gold-field, New Zealand, are in porphyry (p. 553). So are a few in Queensland (pp. 581, 614) and in Victoria (p. 657).

Serpentine.—At Native-Dog Creek, the bed-rock is Silurian shales and conglomerates, with serpentine cliffs; the shales are traversed by a dyke of quartz-porphyry. Near this dyke the rock was very rich, and gold was found in payable quantity as far as the schist and serpentine extended, but not beyond. Some of the heaviest gold was found on the schists, close to their junction with the serpentine.

At Canoona, Queensland, the gold was found to follow the course of a dyke of serpentine. Some of the Queensland reefs are in serpentine-slate. Gold occurs in the serpentine of the Quebec group, Lower Silurian, in Newfoundland (p. 84).

Trachyte.—Gold is contained in the trachytes of the northern part of the Black Hills, Dakota, and in the Bear Lodge Range.

The Report of the U. S. Geological Exploration of the 40th parallel places some of the prominent (auriferous) silver districts of the Carpathians, Mexico, and the United States (Comstock lode, Aurora district, Silver Mountain, Moss lode) in direct association with trachyte.

Preliminary crushings of decomposed pyritous trachytes or felsites from the Tunnel and Green's reefs, Upper Cape, Queensland, yielded about 12 dwt. of gold per ton. A closely similar property is the Peninsular reef, Portobello, Otago, where the diffused auriferous pyrites in greyish-white trachyte gave varying quantities of gold, from 3 to 11 dwt. per ton.

Von Cotta, speaking of the celebrated mine of Verespatak, the "Eldorado of Transylvania," Hungary, connects its gold-veins in some measure with the trachytic outburst of the Csétatye.

Most of the reefs on the Otago gold-field, New Zealand, are in trachyte (pp. 537, 538–9, 560).

MINERAL ASSOCIATES.

The following is a brief summary of the metallic and other minerals found associated with gold and auriferous rocks, arranged alphabetically, with some remarks on the influence apparently exerted by them upon the characters of the ores.

Antimony.—Antimony sulphide (stibnite) occurs at Cata Branca, Minas Geraes, Brazil; at Paciencia and Coelho, Minas Geraes, with tellurium and iron-pyrites; with auriferous iron-pyrites and mispickel at Gold-Kronach, in the Fichtelgebirge; and in many of the Transylvanian (p. 704) gold-ores.

Sulphide and oxide of antimony with free gold, are found at Heathcote, Whroo, Templestowe, Caledonia, Anderson's Creek, Donovan's Creek, in the basin of the Yarra, Rutherglen, Maryborough, Blackwood, Wood's Point, Maldon, Daylesford, Ballarat, and other Victorian localities. The yield of gold from a vein of quartz and antimony sulphide at Sunbury averaged 2 oz. per ton. The antimony-mines of Costerfield gave considerable quantities of gold from every vein. The ore here consists of sulphuret seamed with brown and white oxide of antimony, combined with a small proportion of auriferous quartz: below the natural water-level no oxide is found. The gold and antimony yields of some samples are thus stated:—

Locality.	Variety.	Antimony.	Gold.		
		per cent.	oz.	dwt.	gr.
Ringwood	Sulphide	33	2	5	17
Costerfield	,,	45	2	15	0
,, ...	,,	42	1	19	0
Sandhurst	,,	63	1	10	0
Whroo	,,	65	3	18	0
Costerfield	Oxide ..	36	1	10	16
Newcastle, N.S.W. ..	Sulphide	..	0	15	0

The Costerfield sulphide on smelting gave antimony containing silver, lead, copper, bismuth, arsenic, cadmium, manganese, cobalt, nickel, chromium and iron.

In Victoria, antimony occurs native, in combination with sulphur (stibnite), as oxide (cervantite), as white antimony (valentinite), as red antimony (kermesite), and in some complex minerals, such as tetrahedrite and boulangerite. It accompanies gold in the veins of San Diego co., California. Some of the gold of the Argentine Republic is associated with antimony (p. 208); also much of that in Bolivia (p. 209). Antimony is abundantly associated with the vein-gold of Borneo (p. 289), and occasionally with that of Sado, Japan (p. 356). Veins of auriferous stibnite occur at Langdon's Creek, New Zealand (p. 519), and in the Hohen Tauern, Bohemia (p. 701).

Arsenic.—Mispickel, arsenopyrite, or arsenical iron-pyrites, is very commonly the especially auriferous ingredient of a mixed lode, e.g. the Richmond mine, Nevada.

Mispickel, having the composition of about 55 per cent. iron, 25 arsenic, and 20 sulphur, contains the greater part of the gold for which the rich and well-known veins at Marmora, Ontario, Canada, are worked. Some examples have shown very high proportions of gold (p. 79).

Bismuth.—The sulphide of bismuth occurs at Cata Branca, Minas Geraes, Brazil. Metallic bismuth is found in the Victorian deep leads. Bismuthite is met with in the Victorian deep leads; and at the Chesterfield gold-district, S. Carolina.

At Nuggety reef, Maldon, Victoria, both in the neighbourhood of the granite veins (p. 836) and a few in. deep in the granite itself, occurs the rare mineral maldonite, an alloy of bismuth and gold. Hence the gold from this mine contains considerable proportions of bismuth.

Bismuth occurs with gold in Charlotte co., New Brunswick, giving 10 per cent. of bismuth and 1*l.* worth of gold per ton (p. 83). The auriferous deposits of the Yeniseisk, Siberia, contain bismuth (p. 379). Some of the Queensland reefs carry bismuth (p. 582).

Calcium.—It has been observed by Von Cotta that lime is generally conspicuously absent from rocks associated with gold. On the other hand, in some districts of New South Wales (as Nundle and Denison, Upper Peel and Hunter rivers), the auriferous veins are composed rather of calcareous than silicious minerals, and have been yielding gold for over 20 years. The deep leads of the Lachlan, Australia, are opened on the flanks of a limestone belt; nuggets of gold weighing 2 to 9 oz. are frequently obtained from these leads, enveloped in what appears to be a decomposed silicate of lime. There was a cavern found in the limestone, 60 ft. wide and 120 ft. long, full of ordinary wash-dirt. The influence of calcspar on the veins of Victoria is discussed on p. 649.

Two localities in the Sierra Nevada, California, are recorded as having gold in calcite or dolomite. Auriferous quartz-veins in Dog Island, Manitoba, are in dolomite (p. 80). Most of the rich quartz reefs at Gympie, Queensland, contain abundance of calcite in strong veins and patches, often richly impregnated with gold. A fine specimen from these shows actual veins of largish gold specks irregularly distributed through white opaque calcite. Calcite also occurs in some of the New South Wales (p. 494) and Victorian (p. 684) reefs, and in Bohemia (p. 701).

Apatite is found traversing the auriferous quartz at Pèche, Ottawa (p. 80). The metamorphic Jurassic limestone of Sonora, Mexico, includes the richest gold-placers (p. 113). The Atlantic Cable mine, Deer Lodge co., Montana, is in "a zone or dyke of crystalline limestone which is enclosed by granite" (p. 173). Both calcite and aragonite occur in some of the veins of the Thames gold-field, New Zealand (p. 555). In the Queensland reef, carbonate of lime, gypsum, and selenite are often met with (pp. 582, 583, 584, 591, 592); the Devonian reefs in Queensland are only fairly auriferous when lime or magnesia is present, and cease to be productive on entering a silicious area (pp. 590–1).

Cobalt.—Cobalt occurs with nickel in the Cretaceous gold-veins in Hungary and Afghanistan (p. 270).

Copper.—Native copper in grains is found in the gravels of the Sierra Nevada, California. Copper-ores occur in the Victorian deep leads. In Colorado, very little of the gold is found free in the quartz vein-stone, but is mostly combined or intimately associated with the pyrites, the copper-pyrites being very much richer than the iron-pyrites. The copper of the Sierra Madre, Sonora, Mexico, is said to be sent to China, and to fetch a high price on account of the gold in it (p. 109). In Hayti, gold is found in nests of purple sulphide of copper (see assays, p. 196). Some ore of copper is associated with almost all the gold found in the Argentine Republic. At Coquimbo, Chili, gold is found in a matrix of carbonate of copper. All the gold of the Indian Archipelago contains more or less copper (for assays, see p. 283). The copper of Singhbhum is auriferous (p. 331). Copper is associated with the vein-gold of Japan (p. 353). Copper-ore and native copper occur at a placer on the Murojnaia, Siberia (p. 399). The copper-ores of New Caledonia contain gold (p. 477). Copper-pyrites and the carbonates occur in many Queensland reefs (pp. 581, 584, 592, 593, 594, 595, 596, 602, 603, 605, 610, 611, 613). Copper-ores accompany the gold in some parts of South Australia (p. 625), Victoria (pp. 667, 685), Bohemia (p. 701), Germany (p. 711), Italy (p. 717), and Spain (pp. 720–1).

Diamond.—In the deep leads of Victoria, about 60 small diamonds have been found in the Beechworth district, in the ordinary wash-dirt.

In the placers of Siberia, in those along the flanks of the Appalachian chain, and in those of the Sierra Nevada, California, diamonds occur, as well as at the Cherokee mines, Butte co., California (p. 130).

The frequency of diamonds in the Brazilian gold-placers is quite familiar. They occur, too, in the rivers of N.W. Borneo (p. 284) and Matan (p. 286), in the Mahanadi, India (p. 320), and in Gangpur States, India (p. 324).

Felspar.—Felspar, sometimes porphyritic in character, commonly forms a large portion of the gangue in the auriferous quartz-veins in Colorado.

Garnet.—Garnets are common in the Sierra Nevada gravels, California, in the Victorian deep leads, and in the S. Saskatchewan gold-fields; in the Yeniseisk gold-fields (pp. 379, 387); and in Hungary (p. 707).

Iridium.—Iridosmine [osmiridium] occurs in the gravels of the Sierra Nevada, California, in the deep leads of Victoria, and in the gold-washings of Minas Geraes, Brazil.

Iron.—Chromite occurs in the Victorian deep leads. Iron forms an important ingredient in the celebrated *jacutinga*, the auriferous rock of Brazil (p. 221). Magnetite is found in the Victorian deep leads. Limonite and earthy red hæmatite, or other ferruginous minerals, are the chief constituent of the auriferous *moco de hierro* of Venezuela (p. 265). In the S. Yeniseisk gold-fields, Siberia, the gold is not unfrequently covered with a thin crust of oxide of iron (p. 397). Carbonate of iron occurs in some of the veins of the Thames gold-field, New Zealand (p. 555), on the Normanby gold-field, Queensland (p. 606), and in Victoria (p. 690).

Pyrite [iron-pyrites] occurs plentifully on almost all gold-fields, and is rarely free from traces of gold. At Sandhurst, Victoria, it forms the vein-stuff in some places. In California, it may be said that there is hardly any productive quartz-vein which has not some pyrites disseminated through it, yet the quantity is usually small as compared with the quartz, while in the majority of instances it is much richer in gold. Some interesting tables of comparative values of gold from raw and decomposed mundic are given on p. 589.

The " black " gold of Canoona, and some of that of Sharper's Gully, both in Queensland, is coated with manganic oxide of iron. Vivianite (phosphate of iron) occurs in the Victorian leads (p. 653).

Lead.—Metallic lead is very rare in gold-veins, but the ores of lead, such as galena, antimonial lead, sulphate of lead, carbonate of lead, arseniate of lead, and phosphate of lead, are often met with.

Mimetite, an arseniate of lead combined with a chloride, is found in the Richmond mine, Nevada, always rich in gold. The ore of the Richmond mine is an argentiferous carbonate of lead, with nodules of galena interspersed through it, together with a considerable amount of decomposed arsenical pyrites, which is gold-bearing. Galena is associated with gold in some of the reefs in New South Wales (pp. 493, 495), with those of Otago, New Zealand (p. 532), of Queensland (pp. 583, 584, 592), of Victoria (pp. 649, 658), of Hungary (p. 705), of Germany (p. 711), Italy (p. 717), and Scotland (p. 736).

Though payably auriferous lead-mines are exceptional, no sample of ordinary lead-ore (galena) yet examined has failed to exhibit traces at least of gold. Galena is an important constituent of the gold-ores of many parts of Transylvania (p. 705). The vein-gold of Arizona is almost all in argentiferous galena (p. 129).

In the auriferous veins of chloro-bromide of silver at St. Arnaud, Victoria, mimetite (arsenic pentoxide 23·20, lead oxide 74·96, chlorine 2·39) appears to be pretty abundant.

The argentiferous galenas of Kulu contain gold (p. 347). Galena is associated with the vein-gold of Japan (p. 353). The Balgar-Dagh mines, Turkey, give ores containing 21 per cent. of lead, and 4 gr. of gold per 108 oz. (p. 474).

Magnesia.—Gold occurs in felsite magnesian slate in Newfoundland (p. 84).

Manganese.—Some of the vein-gold in the slates of the Chaudière valley, Lower Canada, is "tarnished by a black earthy coating of oxide of manganese." Manganese is an ingredient of the auriferous Brazilian *jacutinga* (p. 229). Iron manganese occurs in the Yeniseisk placers, Siberia (p. 400). The "black gold" of Canoona, and some of that of Sharper's Gully, Queensland, is coated with manganic oxide of iron.

Mercury.—Rolled fragments of cinnabar occur with the stream-gold in Borneo (p. 290).

Molybdenum.—Molybdenite occurs at the Excelsior gold-mine, California, and in the Hohen Tauern, Bohemia (p. 701).

Nickel.—Native nickel occurs in minute rounded grains, containing traces of iron and cobalt, at Trinity Bar, 5 miles below Fort Yale, on the Fraser river. Also, with cobalt, in the Cretaceous gold-veins in Hungary and Afghanistan (p. 270).

Osmium.—Laurite [sulphuret of osmium and ruthenium] occurs in the gravels of the Sierra Nevada, California. Irid-osmium occurs in the gold-washings of Minas Geraes, Brazil.

Palladium.—Palladium forms 5 to 8 per cent. of the gold-alloy in the Minas Geraes mines. Some assays made at the Rio de Janeiro mint gave the following results :—

	1.	2.	3.
Gold	88·9	90·25	92·3
Palladium	11·1	9·75	7·7

Platinum.—Platinum occurs in some abundance, with its alloys, in the gravels of the Sierra Nevada, California. The chief is native platinum, alloyed with iridium, rhodium, paladium, &c.; and platin-iridium. It is frequent with gold in the Ural placers, at Nijny Tagilsk, Bissersk, Bilimbayewsk, Bogoslofsk, Kushvinsky, Newyansk, Wereh-Yssetzk, Kischtrinsk, and Miask. Also in the Cherokee mines, Butte co., California (p. 130), and in the Tranquille river, British Columbia (p. 51). Much of the Brazilian gold is alloyed with platinum (p. 223). It is found also in Choco, United States of Colombia (p. 236), in the rivers of Assam (p. 280), in Mysore (p. 341), and in the Rhine (p. 714).

Silica.—It is probably unnecessary to mention quartz as the most universally auriferous veinstone; but it must not be supposed that all quartz is auriferous, nor that all gold is quartzose. Other matrices are described in this section.

In New Zealand, "gold sometimes occurs so mixed with silicious particles as to constitute with them a golden sandstone." In Victoria, one pyritous vein consists largely of nearly pure silica, in the form of chalcedony (p. 685).

A portion, at any rate, of the so-called "rusty" gold of the miners would seem to be coated with a film of some silicious mineral, probably silicate of iron, which prevents its amalgamation. Actual samples showing this feature have been gathered from a large deposit of tailings in the Feather river, below Oroville, in Butte county, California; some were wholly, others only partially coated; and while the coating in some cases was opaque, and hid the gold, in others it was semi-transparent, and revealed the metal. Similar specimens have been described by Attwood from Guayana, Venezuela.

Ruby.—Rubies are found in the Victorian deep leads; some of poor quality occur in the Ayakta alluvia, Siberia (p. 407).

Sapphire.—Sapphires occur in the Victorian gold-drifts: in the bed of the Tubba Rubba Creek, Mornington, and at other places, they have been found of a fine blue colour. Blue and green sapphires occur in the Mount Werong field, New South Wales (p. 514).

Silver.—Silver in some form is so universally present in gold of all qualities, varying only in its proportions, that enumeration is quite impossible. It may also be said that no silver-ore is quite free from gold.

In the reefs of the St. Arnaud district, Victoria, the gold is associated mainly with chloro-bromide of silver, which has shown, on analysis, 65·14 silver, 24·16 bromine, and 10·73 chlorine; while the embolite from South American mines gives 66·562 silver, 20·088 bromine, and 13·050 chlorine.

Tellurium.—Tellurium is met with at Paciencia and Coelho, Minas Geraes, Brazil, with antimony sulphide and iron-pyrites. Tellurium is associated with some of the gold of Asia Minor (p. 475).

In many of the mines of Western Transylvania (p. 705), the occurrence of the gold in combination with tellurium is the common feature. Prominent examples are Nagyag (p. 707), Offenbanya, &c. The chief forms are nagyagite (consisting of lead, tellurium, gold, sulphur, and small quantities of copper and silver) and sylvanite (containing tellurium, gold, and silver). These minerals are also found in the Melones and Stanislaus mines, Calaveras, California, and in the Red Cloud mine, Colorado.

Tin.—Rutile, anatase, brookite, and cassiterite occur in the Victorian deep leads. Stream-tin is found with alluvial gold in Borneo (p. 287) and Perak (p. 365), and in the Great Penchenga valley, Siberia (p. 400).

Titanium.—Menaccanite occurs in the Victorian deep leads, in the gold-sands of California, in the Yeniseisk gold-fields (p. 379), and in the auriferous sands of the Dee (p. 734).

Topaz.—Topazes are found in the washings from Morris Ravine, Sierra Nevada, California, and in the drifts of Victoria, some of the latter specimens being very good.

Tourmaline.—This mineral is met with in the Victorian deep leads;

in the Yeniseisk placers (p. 400), notably on the Ayakta (p. 407); and in some Victorian reefs (p. 688).

Tungsten.—Wolfram occurs in the Victorian deep leads, and in the Irish auriferous pyrites veins (p. 728).

Scheelite [calcic tungstate] was found as a gangue for gold by Dr. C. Le Neve Foster in the Italian Alps, at the Val Toppa mine (p. 717), in the Val d'Ossola, near Piedimulera, and is called by the miners *marmor rossa* ("red marble"). Prof. Silliman received a sample of gold in scheelite from the Charity mine, Idaho. Scheelite occurs in the auriferous veins of the Hohen Tauern, Bohemia (p. 701).

Vanadium.—Dr. James Blake found gold associated in considerable quantity with a vanadium ore which has been named roscoelite, at the Sam Simms and Big Red Ravine mines, near Coloma, El Dorado county, California. The gold is found interstratified with laminæ of the mineral, or imbedded in it, in pieces varying from the minutest microscopic particles upwards.

Zinc.—Blende occurs in most of the gold-ores of Transylvania (p. 705). It is sometimes found to be auriferous in Lower Silurian veins in Lower Canada. Auriferous blende is found in some parts of Madura, India (p. 334), and in Japan (p. 353). Zinc is associated with some of the gold of Asia Minor (p. 474), of Otago, New Zealand (p. 532), of Queensland (pp. 581, 583), of Victoria (p. 649), and of Italy (p. 717).

Zircon.—Zircon is common, in minute crystals, in the Sierra Nevada, California; in the Victorian deep leads; in the Gavrilof placer, Yeniseisk, Siberia (p. 387), and on the Ayakta (p. 407); in the Eucumbene river, New South Wales (p. 505); and in the Mount Werong field (p. 514).

CHAPTER III.

SHALLOW PLACERS AND LIVE RIVERS.

THE two preceding chapters have been devoted to an account of the geographical and geological localities of auriferous formations, coupled with some opinions as to their origin and cause: they have, in fact, dealt with the subject in its broad general outlines. The next consideration will be the specific characters of the several formations: and the means employed in extracting the gold from them, occupying the remaining chapters of the book.

Definition.—The term "shallow placers" is applied to auriferous deposits in alluvial ground overlying the "country-rock," and reaching to depths varying from a few in. to many ft. Such are always of recent formation, as opposed to the so-called "deep leads," to be considered in the next chapter. The working of these deposits is often known as "surfacing."

Importance.—It was in these superficial accumulations that gol[illegible] first found by colonists near the foot-hills of the Sierra Nevada, as [illegible] as in the creeks and gullies of Australia; and so rich were they, that even with the primitive appliances in vogue in the early days of the gold industry, 36,000,000*l.* are said to have been got out of the Californian diggings during the first 5 years' work. In fact, until quite recently, since such great progress has been made in quartz mining, at least two-thirds of the gold produced in English-speaking lands has been by washing this superficial *detritus*, and all the Siberian product to this day is obtained from the same source. The reason for this is not far to seek.

Formation.—In these shallow diggings, Nature has for ages been performing the work for which the quartz miner must invent all manner of machinery, and employ a vast amount of capital and skilled labour—the disintegration of the gold-bearing rock and the concentration of the metal. Consequently, the unskilled labourer, whose capital is represented by his own strength and a few of the simplest possible tools, is unable to extract on a remunerative scale immense quantities of gold, which under its original condition, disseminated through quartz and other hard rocks, often in invisible proportions, would have needed vast amounts of capital and much machinery for its elimination, and would in many instances not have repaid the outlay.

Decline.—The exhaustion of the shallow placers of the older gold-fields is fast approaching, that class of mining being abandoned to the "more patient though less skilful Chinese." In New Zealand, surface washing is now almost entirely a Chinese occupation, the careful Celestials being satisfied with the leavings of Europeans, and content to wash the tailings whence the bulk of the gold has been extracted.

But, besides the enormous yield of gold from the shallow washings themselves, which gave men confidence and capital necessary for undertaking the less obviously beneficial exploration of deep leads and quartz veins, they have actually led the miner up to the very doors of these hidden store-houses of wealth. In New South Wales, as in Victoria and California, the deep leads have nearly all been discovered by prosecuting the surfacings on the hill-slopes, and indeed in many instances the outcrops of quartz veins have been accidentally discovered in placer-diggings by teamsters and other similarly unscientific gold-seekers.

Though placer-mining, for many reasons, does not now occupy the leading position it once held, it must still remain highly important, and will continue to take the foremost place in all new gold-fields, whether in old or new countries. For this reason, it is fully deserving of the attention here bestowed upon it.

Characters.—The origin, occurrence, and character of shallow placer-diggings vary considerably. Von Cotta has laid down half-a-dozen rules deduced from the method of formation of placer-diggings which have been singularly verified in practice:—

1. Placers *in loco* will be likely to carry metals in quantity and distribution like the original deposits on which they lie.

2. Alluvial placers of accumulation will be richest in those places where the current of the stream was interrupted by a diminution in its fall, by sudden change of direction, or by the entrance of a tributary; also by reefs, bars, and eddies. The absolute richness, however, depends upon local circumstances, and the size and weight of the floated masses must be taken into consideration.

3. Of course the small depressions, creases, holes, and fissures of the bed-rock over which the current passed are frequently especially rich.

4. The lowest layers of each "period of deposition" (*Schwemmperiode*) are usually the richest.

5. Sometimes, however, several periods of deposition have succeeded each other; and thus several rich strata may occur in the same ground.

6. Not only the courses of present streams, but also, and especially, the ancient channels, now forsaken, are the localities of placers.*

* This paragraph refers to deep leads, which are described in the next chapter.

A "period of deposition" may be understood as the time during which all the mass of alluvial material was subjected to the influence of water. By the cementing process which will be presently described, or by an interruption in the aqueous action, the alluvial layers may become so consolidated as to form an apparently new bed-rock, then termed a "false bottom"; or the accumulation in depth may even be such that the stream fails to have any effect upon the bottom stratum. Wherever shallow placers have been worked, experience has shown that there are frequently two or three "bottoms" and corresponding strata of maximum richness alternating with others comparatively barren. Many old diggings in all parts of the world, supposed to have been quite exhausted, will yet be worked and yield as great riches as before, when this fact is thoroughly appreciated and acted upon.

There cannot be a doubt that in mechanical and not in chemical processes have originated all alluvial gold-deposits, that they have been primarily derived from the disintegration and wearing away of auriferous veins of quartz, &c., exposed to the influence of the weather and other agencies, at or near the then surface of the ground. As a rule, the *detritus* thus formed has been distributed by the power of running water; but that has not always been the case, for sometimes placer-diggings are found on the very outcrops of auriferous veins or reefs, constituting what Von Cotta calls "placers *in loco*." These last, not having undergone any appreciable amount of mechanical concentration and accumulation, are generally, if not universally, much less rich in metal than the placers where the concentrating agency of a stream has been at work. Some placers even are attributed to glacial action (see pp. 222, 224, 737).

It must not be forgotten that this erosion of gold-bearing mineral veins, and the distribution of the drift thus produced, has taken place at two distinct geological epochs, both comparatively recent, but separated by many ages of time. The first series in point of age includes the so-called "deep leads" (described in the next chapter), and is the work of a river-system quite different from that now existing. The second series, of which we are now particularly treating, is entirely due to the streams of to-day, and is being continued by them at this moment. The modern rivers in cutting through (almost always crossing, and frequently at right angles to) the channels of the long extinct water-courses, have redistributed their golden sands and gravels, and in this all the modern placers have immediately originated, except those few which are derived directly from mineral veins.

As may be gathered from what has already been said, placers are generally much richer in their richest parts than the veins from which they have been derived. Moreover, there appeared to be good reasons for supposing that the gold-dust, under favourable conditions, will amalgamate and form nuggets such as are rarely or never found in veins (see pp. 796–7). But, under certain circumstances, the veins may be more productive than the placers to which they have given rise; for example, if the auriferous rock be so hard as to resist disintegration more effectually than the country-rock, so that for a very small amount of the latter eroded there will be an immense mass of the former. But such instances are very rare. On the other hand, however, the amount of material to be removed for obtaining a given quantity of gold is generally much greater in placer than in vein deposits, especially in the case of deep leads and hydraulic workings.

Numerous instances might be given where shallow placers are entirely due to the degradation of quartz veins. In all such cases, the drift will prove barren above the point where the reef crosses it. In some placers in the Sierra Nevada, there is very little alluvium or drift, the gold having all come from ledges near by, which contain auriferous veins. The occurrence of gold-placers below the outcrops of silver-mines is illustrated by the Comstock ledge, which was discovered by following up the alluvial gold-workings to their source. This vein has ever since produced a highly auriferous silver-ore (see p. 173), but argentiferous ores much less rich in gold may in time produce valuable gold-placers, because the silver rapidly disappears by oxidation and solution, while the gold remains unattacked.

In character, placer-diggings manifest almost as great variety as vein deposits. In one case, on the Ballarat gold-field, Victoria, the "wash-dirt" or auriferous alluvium runs in a series of leads of varying width, starting from nearly the same point, and trending in different (sometimes opposite) directions towards the deep leads. In another placer, on the same field, the width of the "gutter" and "reef-wash" was about 100 ft., the depth of the "pay-dirt" about 5 ft. The "leadings" or barren drift overlying the pay-dirt was of black clay, the reef of green slate, and the bottom of sandstone. At a third, the wash-dirt, 4 to 6 ft. thick, was a loose dark-coloured gravel, intermixed with black conglomerate and sandstone boulders. In a fourth instance, the wash-dirt on one lead was a dark-blue or black gravel on a green slate bottom; but there was a second and shallower lead alongside, where the wash-dirt was much lighter in colour. This latter was supposed by some to have been the original water-course, and the former to have been caused by the stream being displaced from its proper channel. By others, it was regarded as a "reef-wash." The Wood's Point district, lying about 90 miles N.E. of Melbourne, has some interesting peculiarities. The formation is schistose, the rocks belonging to the Upper Silurian series, and is traversed by dykes that have cropped out on the surface and are generally richly metalliferous. The valleys are very narrow, and the beds of rivers and creeks are rockbound and rarely exceeding 20 yd. in width. Deep leads are entirely wanting; the wash through which the alluvial miner works down to the beds of the creeks consists invariably of layers of water-worn stones, varying in size from that of boulders to that of pebbles, and is 2 to 12 ft. deep. The gold lies sometimes, but rarely, in a thin layer of sand or pipe-clay on the surface of the bed-rock; more generally, in the crevices of the rock itself, often more or less rotten, which is broken up to a depth of 12 to 20 in., and is occasionally found in what are termed "pot-holes," from the fact that they are of the form and size of a camp pot, say 15 to 18 in. in diameter and 6 to 10 in. deep. In the latter instance, the bed-rock is either a very hard blue schist or soft rotten granite.

In the first instance mentioned, the course of the stream is generally across the "strike" of the rocks, and the gold is found below a hard "bar," as shown in Fig. 30, or on one side of the creek, as in Fig. 31. In the second and third instances (Figs. 32, 33), the stream generally runs

FIG. 30.

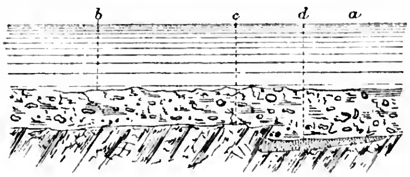


FIG. 31.

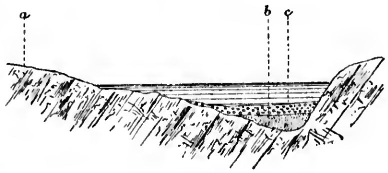


FIG. 32.

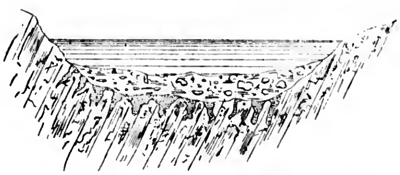
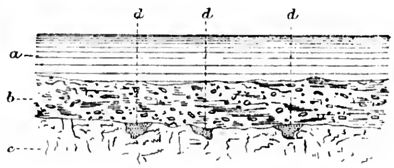


FIG. 33.



SECTIONS SHOWING SHALLOW PLACERS.

with the strike of the rocks, or at a slight angle; but the "dip" is nearly perpendicular in those instances where "pot-holes" have been known to occur. The alluvial gold on these bank workings or creek beds, as already stated, is found chiefly in the bed-rock, which is slate, striking N.W. and S.E., and dipping nearly 90°. Some of these slates are soft and rotten to a depth of 3 ft. or more; others are indurated and crystalline from the surface downwards. These differences occur within 50 yd. or less, and it is on the soft rock only that the precious metal is found. The gold is scaly or flattened. Nuggets are obtained in soft clay lying on the face of the bed-rock, at no great distance from it, say 3 or 4 ft. at most. Whether found *in situ* or drifted, they are believed to be of later date than the reef-gold, or gold found in the bed-rock. In the Goulburn, the bed-rock is commonly covered by a soft layer of heavy slate and granite boulders, in pipe-clay, some 2 to 6 ft. deep; and above this is frequently found a bed of clay and pebbles, a few in. to 2 ft. thick; and then a drift composed of large flat stones, much water-worn, cemented with clay and ironstone grit, sometimes 6 to 8 ft. thick. The stones are flat, weighing as much as 2 cwt., and elongated, their longer axis lying with the current, and their pointed ends up the stream. The last two drifts mentioned are sometimes absent, and in their stead is a heavy bed of red clay, with small quartz and slate breccia. The "colour" is got in all the drifts, but the best results are obtained from the bed-rock, from which may perhaps be inferred that the chief and earliest deposits of gold in these ranges are contemporary with the first great denudation of the granitic dykes, which are much more numerous than at present appears. At the heads of the water-courses thereabouts, granite is never entirely absent, and the miners look for a greasy wash near the bottom as the most favourable symptom. Small deposits of wash are found high up on the spurs even to 1200 ft. The gold lies in these cases in a soft clay, and is "shotty" and without quartz. Nearer the bed of the river, however, where some of the bank claims have proved very rich, the gold is again found chiefly in the slate; and the drift above the bed-rock is composed of slate boulders and clay, the granite boulders being less frequent and not so large as in the bed of the river.

It is a curious fact that deep pools under waterfalls in auriferous streams seldom contain an appreciable quantity of gold. Many such have been worked out in expectation of a rich harvest, but with disappointing results. All large auriferous rivers show analogous cases; in them the gold is always found on the bars or points, and not in the deep pools or bends.

Sections of strata.—Brough Smyth, from whom much of the information in this and the succeeding chapters is derived, justly observes with regard to sections of the strata found in placer mines, that, though they may be and are generally uninteresting to the geologist, they are nevertheless highly valuable to the miner, and that if there had been many such sections procurable at the time when the placer-diggings of Victoria were first opened, much useless expenditure of time, capital, and labour would have been avoided. No apology, therefore, is needed or introducing a few sections here, principally from the Victorian fields :—

	ft.	in.
1. Original surface—dark loam	6 in. to 1	0
Sand, with very small fragments of slate and quartz, very sharp and angular	1 ft. to 2	0
Compact sandy gravel, changing gradually to quartz gravel, particles increasing in size towards the base of the stratum	5	0
Sand and gravel, principally sand, without quartz pebbles	1	0
Auriferous drift—gravel, and with very fine quartz, and a small proportion of sandstone intermixed with large quartz boulders, 6 to 12 in. in diameter	1 ft. to 5	0
Decomposed bed-rock, very compact white clay	9 in. to 1	0
	15	0

	ft.	in.
2. Surface soil, say	0	9
Sand mixed with fragments of quartz and sandstone (not water-worn)	1 ft. to 2	0
Hard dark clay	0	3
Red and yellow indurated clay in alternate layers of about 2 in. in thickness	1	0
Gravel intermixed with fine quartz	6 in. to 1	0
Layers of red and yellow indurated clay, sand and soft sandstone in alternate layers, 3 to 4 in. thick	1	0
Fine gravel with fragments of angular quartz	0	6
Auriferous drift—coarse gravel with fine quartz, and a small quantity of sandstone (not water-worn), and large quartz boulders ..	3 ft. to 4	0
Decomposed bed-rock, pipe-clay	6 in. to 1	0
	11	6

	ft.	in.
3. Surface soil, say	1	0
Hard sandy soil slightly mixed with gravel and a small proportion of very fine angular quartz	8	0
Auriferous drift—loose gravel intermixed with fine quartz and sandstone in small proportion, and large quartz boulders	8 in. to 1	0
Decomposed bed-rock, pipe-clay	6 in. to 0	8
	10	8

	ft.	in.
4. Surface soil, say	1	0
Sand mixed with angular fragments of quartz and sandstone ..	1 ft. to 2	0
Hard dark clay of reddish-brown colour	4 ft. to 5	0
Loose gravel intermixed with fine quartz	8 in. to 1	0
Loose sandy gravel, more compact in the lower part	5 ft. to 6	0
Sand, gravel, and quartz	2	0
Auriferous drift—loose gravel with sand and small angular fragments of quartz and schist	3 ft. to 7	0
Decomposed bed-rock—pipe-clay	6 in. to 1	0
	25	0

Of this last drift, it is remarked that the ground gradually deepens as it is followed northwards, until it becomes a "deep lead." In some parts, it would seem that the older drift has been much denuded, and only the lower layers left, upon which newer auriferous drifts have been superimposed. The miners not infrequently penetrate a "false bottom," which is covered as usual with rich wash-dirt and, after sinking through sand, gravel, and clay, reach another layer of wash-dirt immediately overlying the true bed-rock. It is only by a careful survey, and noting the sections, that it is possible to say how many auriferous layers may exist in an alluvial digging.

		ft.	in.
5.	Surface soil	2	0
	White indurated clay	20	0
	Light-brown sandy gravel	1 ft. to 5	0
	Conglomerate red and brown, and water-worn quartz	1 in. to 0	4
	Wash-dirt with rough reef-gold mostly attached to fragments of quartz	6 in. to 2	0
		29	4

		ft.	in.
6.	Loam	4	0
	Red clay and gravel	13	0
	Reddish clay	18	0
	White clay and sand	12	0
	Red gravel and sand	8	0
	White clay and gravel	7	0
		62	0

The wash-dirt, composed of white clay and gravel and small pebbles of quartz, is about 1 ft. in thickness.

7. Yellow clay on the surface, with layers of red and white gravel intermixed with a heavy wash of boulders and gravel on the bottom—composed of slate and soft pipe-clay (decomposed mudstone). The wash-dirt taken out at the first rush varied from 1 to 3 ft. in thickness, but since then many parts of the strata reaching from the surface to a depth of 20 ft. have paid for washing.

8. The depth of the shaft was 85 ft., through stiff clay, gravel, and cement. The wash-dirt was white gravel, intermixed with heavy boulders on a soft pipe-clay bottom; its thickness being 2 to 5 ft.

		ft.	in.
9.	Top soil	0	6
	Red clay	7	6
	Quartz gravel and red clay	7	0
	Greyish-coloured sand	6	0
	Gravel and quartz boulders, ironstone and pieces of slaty rock cemented with clay	8	0
	Fine red gravel and ferruginous clay—auriferous	2	6
	Soft yellow-coloured clay-slate	..	
		31	6

		ft.	in.
10.	Top soil	1	6
	Red clay	6	0
	Red gravel and cement	8	0
	Sandy clay and gravel—wash-dirt	1	0
	Argillaceous schist covered with pipe-clay	..	
		16	6

The greatest depths mentioned by no means indicate the maximum limits of the thickness of placer-diggings, for shafts have been sunk through similar strata to the extent of 300 ft. without reaching the true "bottom" or "bed-rock."

Conditions, favourable and unfavourable.—The first great desideratum in placer-working is water, for mechanically removing the valueless constituents of the "pay-dirt" or "wash-dirt," i. e. the auriferous stratum and leaving the gold behind. Without the possibility of obtaining an abundant supply of water, diggings of high promise may be quite unavailable.* The merits of an auriferous patch may therefore be summed up in a great measure by the ease and cheapness with which a sufficiency of the element may be obtained. But a second and equally important point is the disposal of the "tailings" or waste material from which the gold has been extracted, or which has had to be removed in order to reach the gold-bearing layer. The neglect of this second point has often entailed fruitless expenditure. Of course, both conditions apply with redoubled significance to hydraulic mining; but it may be well to cite a few instances proving their weightiness even in shallow placers.

In the Government Reports on the gold-fields of New Zealand, for example, are to be found such remarks as the following:—

"Sluicing operations are brought to a standstill from a dread of damages consequent upon the deposit of tailings" on other people's property.

Again, "The ground thus occupied has long been known to be auriferous, but for want of fall it could not be worked. None of the claims can be wrought until the opening of a channel affords the long-desired means of sending away the waste water and tailings from the workings."

The falling-off in production at another diggings is attributed "principally to want of water"; and again, "the claims can only be worked by running the tailings through private property, and in course of time the lowest-lying portion of the ground must be covered up with the waste of sluicing if the workings continue."

On the other hand, floods are equally injurious, and, where prevalent, must be provided for by what is known as a "storm-channel," otherwise the whole "plant" on a diggings may be carried away in a few hours.

In Australia, too, flatness of the ground is a great obstacle in some cases, though not necessarily insuperable.

Similarly, in the Western States of America, the depression in placer-mining in 1870 was caused in a great measure, according to Ray-

* Some plans of "dry washing" are described on p. 881, but they do not seem to have achieved great success.

mond, by "the filling and choking up with tailings, after a few seasons of washing, of the ravines, gulches, and rivers which served as outlets from the ground, thus preventing the maintenance of 'flumes' of sufficient length and grade to disintegrate the hard cement found underlying the top dirt, and rendering imperative the construction of long tunnels to the nearest deep stream, requiring, in some cases, years of labour and the disbursement of large sums without immediate returns." So in another instance—"The future of the region under consideration will depend to a great degree upon finding an outlet for its vast quantity of hydraulic dirt. This can be obtained in some places by 'bed-rock tunnels'; but at other points these are impracticable, and effectual accommodation can only be had by emptying the streams and gulches of their accumulations of tailings." A prominent example of the extent of these accumulations is the Bear river, in California. "This stream has been filled to a depth of nearly 80 ft. in the centre, and its former banks so far covered that tall pine-trees, formerly far above the stream, have been gradually engulfed season by season, until now only the top branches appear above the current." The quantity of tailings here, estimating "an average width of 300 ft., a depth of 75 ft., and a length of 10 miles, would be 44 million cub. yd. It is believed that these tailings contain enough gold and quicksilver to pay a handsome profit for their removal, if an outlet could be found."

The presence of bed-rocks cropping out on the surface is a valuable guide to explorers, enabling them to follow the trend of such alluvial patches as they may discover. As a rule, the gullies or little rivulets having their sources near the outcrops of auriferous quartz veins may be expected to be rich. Victorian miners believe that hills with quartz gravel and quartz boulders on the surface are most likely to prove auriferous.

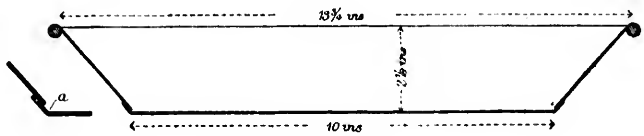
Influence of bed-rock.—It will have been noticed already that the character of the bed-rock exercises an important influence upon the nature of the deposit. Slate forms one of the richest bed-rocks, as the gold accumulates behind the natural "riffles" or checks produced by its edges. In some of the chief diggings in Victoria, it has been noticed that hard sandstone bottoms were the richest; and in many cases, the gold has been found to penetrate as deep as 3 or 4 ft. in narrow crevices. The slates, and decomposed mudstone and clay bottoms were less rich in comparison. In one case, the gold in the deep ground was quite black, while that from the shallow parts was clean and bright.

Object in placer-mining.—The object which has hitherto guided the operations of the placer-miner has almost always been to take the cream, if one may use such an expression, and to leave the skimmed milk, to hurry through the ground, taking out the bulk of the gold with the greatest possible economy of time and labour, and to let the rest go. This is one great reason why the patient Chinese can make a living out of ground that has been abandoned by Europeans. The evils of such a practice are self-evident: very much of what is left is so disseminated, and the ground is rendered so unworkable, that it is doubtful whether it can ever be recovered. Men are now, however, beginning to realize the importance of taking a little more care to save as much as possible of the precious metal, and the various improvements in machinery, &c., which have been attempted, especially for catching the fine gold, will be described in detail.

Principle of gold-washing.—The whole theory and practice of separating alluvial gold from the earthy matters and minerals with which it is found is dependent upon the high specific gravity of the precious metal; and all apparatus used in the operation is constructed and arranged on the principle that, while water has the power of removing the base material, the gold is almost entirely left behind.

Pans and panning.—The gold-digger's "pan" resembles a frying-pan without a handle (Fig. 34); indeed, in the early days of gold-washing,

FIG. 34.



GOLD-WASHING PAN.

that humble household article was very frequently appropriated to the purpose. It is generally made circular in form, 10 to 14 in. in diameter at the bottom, but 3 or 4 in. wider at the top, as the sides, which are about 5 in. deep, are made to slope outwards to that extent. It may be made either of stout tin-plate or thin sheet-iron. The latter material is preferable, as well on account of its greater strength, as because it is not attacked by mercury, which it is sometimes convenient to use. The best pans now used in California are stamped out of one piece of Russian iron of the finest quality, and strengthened by a stout wire in the rim.

Simple as the process of panning appears to be, dexterity is only acquired by considerable experience. In outline it is as follows (see also pp. 28, 33, 100, 121):—A quantity of the dirt to be washed is placed in the pan, sufficient to occupy about two-thirds of its capacity, and the pan with its contents is then immersed in water, either in a hole or in a rivulet, of such a depth that the miner can conveniently reach the pan with his hands while it rests on the bottom. The object of this is to give the operator free use of both his hands for stirring up the mass, so that every particle may become thoroughly sodden and disintegrated. Of course the pan may be held in one hand, and its contents stirred by the other, but the disadvantages of such a method are obvious. When the dirt has become thoroughly soaked and permeated by the water, the pan is taken in both hands, one on either side, and a little inside of its greatest diameter, and, without allowing it to emerge from the water, it is suspended in the hands, not quite level, but tipping somewhat away from the person. In this position, it is shaken so as to allow the water to disengage all the light earthy particles, and carry them away. When this has been concluded, there will remain in the pan varying proportions of gold-dust, heavy sand, lumps of clay, and gravel-stones. These last accumulate on the surface, and are picked off by hand and thrown aside; the lumps of clay must be crumbled and reduced by rubbing, so as to be carried off by the water during the next immersion of the pan. A neat turn of the wrist is required to allow the muddy matters to escape in driblets over the depressed edge of the pan, without exercising so much force as to send the lighter portions of the gold after them. At last, nothing remains in the pan but the gold-dust, with usually some heavy black sand and a little earthy matter. By the final careful washing with plenty of clean water, the earthy matters can be completely removed; but the heavy iron-sand cannot be got rid of by any method based upon its specific gravity relatively to that of gold.

Removing iron-sand.—To effect this, one of two eminently simple plans must be adopted. If the iron-sand be magnetic, as is usually the case, it may be eliminated to the last grain by stirring the mass carefully with a powerful magnet, care being taken that no particles of gold become mechanically suspended among the black sand. Where this is ineffectual, recourse must be had to "blowing." For this purpose, the mass of gold-dust and iron-sand is allowed to become perfectly dry, and small quantities at a time are placed in an instrument called a "blower,"—a sort of shallow scoop, made of tin and open at one end. Holding the "blower" with its mouth pointing away from him, and gently shaking it so as constantly to change the position of the particles, the operator blows gently along the surface of the contents, regulating the force and direction of his breath so as to remove the sand without disturbing the gold.

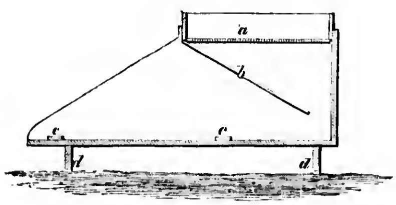
Despite the many improvements introduced from time to time in gold-washing appliances, the pan yet remains an essential part of the gold miner's outfit. Many million pounds sterling were in the early days extracted by its aid alone, and it is still used for final panning out the rich mass of gold or amalgam collected in the various apparatus now employed. On new gold-fields, it continues to be the principal implement in use, as men are not able to carry machines to a "rush," and have no time to make them when they arrive at the scene of operations. As a receptacle for gold, amalgam, or very rich dirt, it is always handy.

Batea.—A modification of the pan is the *batea*, used principally in the Brazilian gold-washings and mines (see p. 217). It is a shallow circular plate, usually turned out of a single piece of wood, about 20 in. in diameter and 2½ in. deep in the centre, the slope being gradual and regular to the outer edge. It requires peculiar manipulation and some degree of skill.

Horn spoon.—Another simple contrivance similarly applied is the horn spoon. It is made by cutting a piece obliquely out of a large ox-horn, so as to measure about 8 or 10 in. long and 3 in. wide, and is then scraped down to a suitable thickness. A horn that is black at one end makes the best spoon, as the gold is so much more readily seen against a black surface. It possesses many good qualities, and is a favourite among prospectors; the desired qualities are chiefly lightness, durability, and its not becoming enfilmed with air or grease, so as to prevent the perfect contact of the water on its surface.

Cradle or rocker.—The methods and implements chosen in working alluvial gold-diggings are almost entirely dependent upon the supply of water at command. The pan requires the least water of all, and properly stands first in the list of apparatus; but if sufficient water be available, it may be discarded in favour of the cradle. This apparatus is so called partly from its outward resemblance to an ordinary nursery cradle, and partly because it is provided with similar rockers, and is caused to oscillate in a like manner. Fig. 35 shows a longitudinal section of a cradle, which is usually about 40 in. long and 20 in. wide, the back end 15 in. to 2 ft. in height, and the sides sloping down from that to about a couple of in. at the mouth. The movable riddle or hopper *a* fits exactly into the top of the cradle, so as to sit steady when the latter is in motion. It is about 20 in. square and 6 in. deep, with a bottom of sheet iron closely perforated with ½-in. holes—at least that is the general size, though not necessarily adhered to when the pay-dirt is very fine. Below the grating, hangs a curtain or apron *b*, of canvas, blanketing, or other suitable material. This is made by stretching a piece of cloth, or whatever the material may be, on a

FIG. 35.



GOLD-WASHING CRADLE.

framework, which is introduced from the mouth of the cradle, and rests on fillets on the sides, sloping from the mouth of the cradle towards the angle formed by the junction of the bottom and the back. Crossing the bottom of the cradle, are nailed a couple of "riffle-bars" *c*, one near the middle, the other towards the outside edge, and each about $\frac{3}{4}$ in. high. The apparatus stands on rockers *d*.

The mode of working with this apparatus is as follows. Some auriferous earth is thrown into the riddle, and the operator then proceeds to rock the machine with one hand while he pours water over the dirt with the other. Under these continued influences, the dirt disintegrates rapidly, penetrates the bottom of the riddle, and, falling on the apron, is conveyed to the inner end of the cradle floor, whence it flows back over the riffle-bars and out of the mouth, the cradle being placed on an inclined plane when at work, so that the difference in level at the hopper end and the mouth end shall be commonly about $2\frac{1}{2}$ in.; but this is subject to modifications to suit special kinds of dirt and the fineness of the gold. Almost all pay-dirt contains more or less stones of various sizes, which will be retained in the riddle, unless small enough to pass through the grating. Those which are so large as to interfere with the working of the cradle are at once picked out and thrown aside, without checking the operation; but the smaller ones are allowed to accumulate, both because their removal in bulk wastes less time, and their presence in the riddle assists the process of disintegration of the earthy matters found in the gravel. When the hopper has become quite full of stones, all washed clean, they are tipped out and carefully looked over for any nuggets of gold which may be among them. The finer particles of gold will collect behind the riffle-bars on the bed of the cradle, while a certain amount of the very fine gold will be caught by the hairs of the blanket-apron. From these receptacles, the gold, heavy iron-sand, &c., have to be gathered periodically, the intervals depending upon the nature and richness of the auriferous earth under treatment. This proceeding is termed "cleaning up," and generally needs to be done two or three times a day. The hopper is removed, and the apron is then withdrawn and carefully washed in a bucket or other vessel containing clean water, which dislodges the gold that may be entangled among the hairs, so that it can be recovered from the bottom of the vessel. Next, the gold and other matters which have collected behind the riffle-bars are scraped up with an iron spoon, and subsequently panned out.

As the weight of water required for cradling is at least three times as great as that of the material to be treated, it is better to carry the latter to the former than *vice versâ*. Of course to be able to convey the water by its own gravitation to the spot where the washing is to be done is of immense advantage. Care must be observed to have sufficient fall and outlet for the "tailings." The water may be conducted into a little pit to serve as a reservoir near at hand for the cradler to ladle it out, or it may be more conveniently laid on by pipes or wooden gutters so as to flow into the top of the riddle.

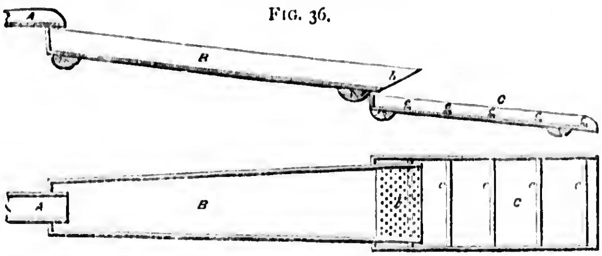
It is possible for one man to work with a cradle; but it is disproportionately inconvenient, as he has to be stopping repeatedly to introduce fresh supplies of dirt and to empty the riddle, and during these delays the sand will pack hard and fast behind the riffle-bars, and have to be removed each time before operations can be recommenced. Nevertheless one man can wash 1 to 3 cub. yd. daily, according to the clayey nature of the dirt under treatment. A division of the labour between two men is much more economical, as one can be constantly rocking and supplying or regulating the supply of water, while the second keeps the riddle fed with fresh dirt.

Cradling is neither expeditious nor economical. it loses fine gold, the sand has a great tendency to pack behind the riffle-bars, and its working capacity is not more than one-fifth of that of the tom and less than a tenth of that of an ordinary sluice; but it is very cheap, requires little water, and is eminently portable. For these reasons, it is especially adapted for washing in gullies where the gold is coarse, and water scarce or uncertain, as is commonly the case in Australia, and there the cradle is still a valuable implement. It is a great favourite with the Chinese in California also. The use of mercury in the cradle is not advisable.

Burke rocker.—The Burke rocker, of S. Carolina, is longer than the ordinary rocker, and has a perforated plate of sheet iron, with holes ½ in. in diameter, in the upper part, through which the fine materials fall into a riffle-box below, formed of shallow compartments, 5 in. apart, wherein mercury is placed. The machine, set on an incline, is rocked by means of a lever attached to the side, whilst a second person throws on the dirt, and removes the coarser gravel. It is said by Tuomey to do twice the work of the ordinary rocker. The Burke rocker as used in Virginia is described on p. 188.

Toms.—These followed next after cradles or rockers, and have been made of several different forms. The old-fashioned "long-tom," now probably extinct, was made about 14 ft. long and with a uniform width of about 18 in.; but this gave way to the Victorian, Jenny Lind, or broad-tom, usually about 6 or 7 ft. long, 12 in. wide at the upper end, and 3 ft. at the lower. It really consists of two distinct troughs or boxes placed one above the other, as shown in Fig. 36. A stream of water flows in by the spout *d*, just over the place where the dirt is introduced into the upper box or "tom" proper *a*. The dirt is constantly thrown in by one man, while a second is occupied in stirring it about with a square-mouthed shovel, or a fork with several blunt prongs, which is more useful for pitching out the heavy boulders that sometimes occur, and for tossing back undissolved lumps of clay against the current. To save wear and tear, the floor of the tom is lined with ⅛-in. sheet iron.

FIG. 36.



GOLD-WASHING TOM.

The lower end of the tom is cut off obliquely, so that the mouth may be stopped by a sheet of perforated iron, such as forms the bottom of the cradle-riddle already described. The apparatus being placed on an incline amounting generally to about 12 in., the materials all gravitate with the water towards this sloping grating at the mouth, everything passing through it save the large stones, which gather on the grating and are removed as often as necessary. Beneath this grating *b*, stands the riffle-box, into which all the fine matters, including the gold, descend. The riffle-box, like the tom proper, is made of rough plank, and is also placed on an incline, but only just so that the water passing over it will allow of the bottom becoming and remaining covered with a thin coating of fine mud. In this way, the gold and a few of the heaviest minerals will find their way to the bottom and rest there, especially by the help of the riffle-bars *c*, which give their name to the apparatus. Sometimes a little mercury is put behind the riffles, so as to assist in retaining the gold, and occasionally the riffle-box is supplemented by a series of blankets, which are useful for catching the very fine gold. The Californian tom, which is the one shown above, differs from the Victorian only in proportions, being generally about 12 ft. long, 20 in. wide at the upper end, and widened gradually to 30 in. at the mouth. Toms are supported on stones, logs, or trestles, as occasion may demand. They are cleaned up periodically, and the gold and amalgam are panned out as with cradles. They employ 2 to 4 men, according to the character of the dirt and the supply of water. They are applicable to diggings where the gold is coarse; but, though generally free from the drawback of the cradle—the caking of the sand—they are quite incapable of saving all the fine gold.

In Dutch Guiana, as I am kindly informed by J. Jewell, the long-tom used is 10 ft. long and 2 ft. wide inside (built of $1\frac{1}{2}$-in. plank), to which is attached a contrivance called a "torpedo." A false bottom is put on the floor of the long-tom, consisting of $\frac{1}{2}$-in. plank, which is removed each time a clean-up is made. The torpedo is a sloping (upwards) iron plate 4 ft. long, of the same width as the floor of the tom where it is joined to the latter, but narrowing considerably towards the end where it meets a riffle. The plate is perforated with $\frac{1}{2}$-in. holes placed $1\frac{1}{2}$ in. from centre to centre; the plate is $\frac{1}{4}$ in. thick. There is a false bottom similarly perforated in the torpedo, and another in the launder leading away from the riffle, and measuring 10 to 14 ft. long. If the torpedo is properly arranged, no gold should be found beyond the riffle.

Sluices.—Sluices were introduced very soon after the tom, and quickly supplanted it in general use. There are several essentially different forms of sluice, whose peculiarities will be noticed in due course; but every sluice consists mainly of an inclined channel, through which flows a stream of water, breaking up the earth which is thrown into it, carrying away the light barren matters, and leaving the gold and heavy minerals. Generally, they may be classified as "box-sluices" and "ground-sluices," the former being raised above the surface and necessitating the lifting of the pay-dirt into them, the latter being sunk below the surface.

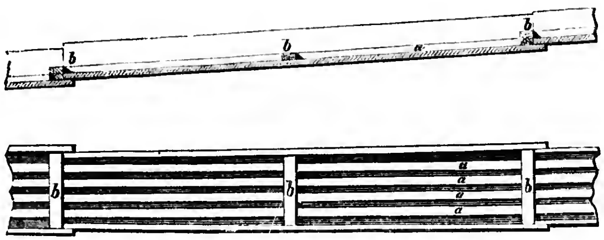
Box-sluices.—The box-sluice or board-sluice, as it is also called, is a long wooden trough or series of troughs, and is now probably the most important implement used in placer-mining. Its length varies from 50 to several hundred or even several thousand ft., its width is never less than 1 ft. nor more than 5 ft., being generally 16 to 18 in., and the height of the sides varies from 8 in. to 2 ft. For convenience and speed in construction and removal, the sluice is made in sections or lengths of about 12 or 14 ft. It is built of $1\frac{1}{2}$-in. rough planks, the bottom boards being sawn 4 in. wider at one end than at the other, so that the narrow end of one box telescopes into the broad end of the next throughout the whole series, and beyond this no nailing nor fixing of any kind is required. This line of troughs rests on trestles, and is so arranged that there is a descent throughout the whole series. The amount of this descent, incline, or "grade" ranges from 8 to 18 in. per 12 ft. A fall of 8 in. in 12 ft. is called an "eight-inch grade," and so on. Generally the grade is uniform throughout, but that is not invariably the case. Many points have to be considered in deciding the grade of a sluice, and it is inadmissible to have less than 8 or more than 20 in. fall in each 12-ft. length. It is important that the sluice should be conveniently near the level of the ground at the point where the pay-dirt is introduced, and this will naturally have a bearing upon the grade, as will also the character of the pay-dirt and the length of the sluice. The steeper the grade the more quickly the dirt is disintegrated, but the more likely is the fine gold to be washed away by the force of the water. The tougher the dirt the steeper must the grade be; tough clay, for instance, does not dissolve so quickly in a slow current as in a rapid one. The shorter the sluice the smaller the grade should be, as there is more danger of the fine gold being lost in a short sluice than in a long one. The steeper the grade the greater the amount of work it can do. As ordinary pay-dirt is generally completely dissolved in the first 200 ft. of a moderately low-grade sluice, the extra length is useful only for catching the gold; sometimes therefore the grade of the last part of the sluice is reduced. Occasionally it happens that the clay is so tough that it will roll for $\frac{1}{4}$ mile in large balls, not only refusing to break up, but also doing much mischief by picking up the gold in its passage. Such clay must not be put through a sluice, but submitted to a puddling process, to be described hereafter.

The sluice-box used in Dutch Guiana is thus described to me by J. Jewell. A large box on the line of the sluice receives the auriferous alluvium; here a man stands with a wooden rake to keep the clayey and sandy matters in motion. The sluice is made in 10-ft. or 12-ft. sections, about 1 ft. wide, and with a total length of 80 to 100 ft. if possible. Riffles are placed at each junction. At the third length of the sluice stands a boy, whose duty it is to catch all lumps of clay and transfer them to a small puddling-box, 5 ft. × 3 ft., which is joined to the side of the first length of the sluice; here they are thoroughly broken down by means of water brought in from the main supply, and are finally let out as soft mud into the first length of the sluice, to be washed again like the other material.

False bottoms and riffles.—When the grade of a sluice is very low—say 1 in 40 or 50—the gold is easily caught, and much of it would rest even on the comparatively smooth floor of the sluice; but additional means of catching it are always adopted. When stones are plentiful in the wash-dirt, a small bar may be placed across the lower end of each trough, to prevent the bottom from being run bare. From such sluices, it is usual to throw out all stones as large as a doubled fist, for which purpose a fork with several blunt prongs, called a "sluice-fork," is used. The same serves to loosen occasionally the materials which have collected behind the bars, and in all sluices watchfulness has to be exercised that the boxes do not choke, and thus send the contents over the sides to be lost.

Some kind of false bottom is almost always used in the sluice, destined to catch the gold and save the wear and tear on the floor of the sluice itself. In Victoria, where the water supply is limited and the sluices are of moderate scope—often only 25 to 60 ft.—boards bored with as many 1-in. or $1\frac{1}{2}$-in. holes as there is room for are fitted into the troughs. In California and elsewhere, the false bottoms are generally composed of longitudinal riffle-bars, about 6 ft. long, 3 to 7 in. wide, 2 to 4 in. thick, two sets being required for each length of the trough or sluice. Fig. 37 shows the mode of arranging the riffle-bars *a* in the sluice. They are kept in place by cross wedges *b*, at a distance of 1 to 2 in. apart, and are not nailed, as they have to be removed at every cleaning up. Into the spaces thus formed, the gold and other heavy bodies will fall, always

FIG. 37.

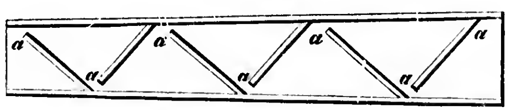


BOX SLUICE, SHOWING FALSE BOTTOM.

sinking through the lighter particles to the bottom. When the sluice-boxes are no longer fit to be used, or for any reason are not to be used any more, they are dried and burned, and, by very carefully washing the ashes, enough gold is often got to buy a new set of boxes.

Block- and zigzag-riffles.—Where there is a great quantity of pebbles and boulders in the pay-dirt, the riffles just described are worn away very rapidly, sometimes in a week or less. It is then advisable to use "block" riffles which, though more expensive, last three times as long, and therefore save much labour. Instead of being sawn longitudinally with the grain of the wood, they are cut across the grain, so that the fibres stand upright in the sluice-box as in the living tree. But it is difficult to procure these riffle-bars more than 3 ft. long, and they are therefore fixed transversely about 2 in. apart.

FIG. 38.



ZIGZAG RIFFLES.

The arrangement of zigzag-riffles is illustrated by Fig. 38. The first bar is nailed to the bottom at an angle of 45° to the side of the sluice, and reaches diagonally across to within an inch or so of the other side. Immediately below this space *a*, another bar is fixed at a right angle to the first, and reaching from that side of the sluice-box to within an inch or so of the other side, and so on alternately for a considerable distance. The sluice always terminates, however, with a certain stretch of the ordinary longitudinal riffles, as the gold and heavy matters are not completely caught by the zigzag-riffles, but only caused to follow a tortuous course, while the lighter materials are swept right over them.

Howland's riffle.—Howland's riffle, made by Morey and Sperry, 92, Liberty St., New York, is made in sections, of cast iron. Each section forms an anticlinal ridge, and is corrugated with parallel channels running up and down the inclined sides, and contains a number of troughs for holding mercury. The eddies produced by these riffles are claimed to present great facility for the valuable matters to exercise their superior specific gravity, and sink into the grooves, while there is considerable exposure of mercury, with which the gold is thoroughly brought into contact.

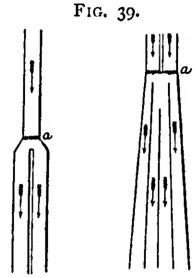
Amalgamation.—Though the heavy particles of gold would be effectually caught by the contrivances mentioned, an immense amount of fine gold would undoubtedly escape, but for some additional safeguard. One of the means best adapted to this end is to form an amalgam, by introducing mercury to the presence of the gold. This is done in several different ways. When using zigzag-riffles, as last mentioned, a vessel containing mercury and pierced by a small hole which allows the metal to escape in minute portions, is placed near the head of the sluice. Trickling down from riffle to riffle, it overtakes the gold, absorbs, and retains it, the amalgam thus formed being caught in the longitudinal riffles farther down. In the ordinary longitudinal riffle-sluice, some mercury is poured in at the head of the sluice about 1½ or 2 hours after starting the washing, and gradually finds its way down with the current, but remains principally in the upper boxes. Smaller quantities are introduced at intervals lower down, the quantity being increased in direct proportion to the amount of fine gold present. Another plan consists in impregnating the pores of the wood forming the riffle-bars with mercury. This is effected by driving a piece of gas-piping ground thin at one end into the wood, and filling it with mercury: the pressure of the column forces a certain amount into the fibres of the wood. This catches the gold, and the resulting amalgam only needs to be scraped off the surface of the wood. The method is rarely used, however, and not generally recommended.

Copper plates.—A fourth plan, of whose efficacy glowing accounts have been given, especially when there is much exceedingly fine gold in the wash-dirt, is the amalgamated copper plate. It is considered as effective for saving fine gold as an equal surface of mercury, being at the same time cheaper and more easily managed. It measures generally 3 ft. wide and 6 ft. long, varying in accordance with the capacity of the sluice. Sometimes the stream is split and carried over 2 or 3 separate plates. It is placed nearly level, and at a considerable distance from the head of the sluice, as it is intended only for catching the very fine or "float" gold, and for this reason also a sheet-iron screen perforated with holes $\frac{1}{2}$ in. × $\frac{1}{16}$ in. is placed in front of it, so that only the finest particles pass over it. It is amalgamated by first washing over its upper surface with weak nitric acid, and then applying some mercury, which has been treated with dilute nitric acid, to form a little nitrate of mercury. If the operation is once effectually performed, it will never need repetition, some fresh mercury only being dropped on it as fast as the gold converts it into amalgam. Two points essential to success are that the current be slow and shallow, so that every particle of gold may come into contact with the face of the plate, which is the principal reason for dividing the stream when the sluice is a large one. A freshly-amalgamated plate is liable to become coated with a green slime due to the formation of subsalts of copper, and is then incapable of absorbing the gold. This slime must be carefully scraped off, and the place where it has been must be rubbed with fresh mercury. It has been observed in practice that when a grain of gold has attached itself to the surface of a copper plate, other particles gather around it, evincing a marked preference for those portions to which gold has already adhered over those which are still free from it; therefore the amount of amalgam allowed to collect without being cleaned off will depend chiefly on the means that can be adopted to prevent its being stolen. To remove the amalgam, the plate is taken up and heated to such a degree that the hand cannot be borne on it, except momentarily; this suffices to render the amalgam soft and loose, and it may then be easily scraped off. The plate is allowed to cool, and is again rubbed with a little ordinary mercury, to make it ready for further use. The plate employed should not be less than $\frac{1}{16}$ in., and must be handled with great care, as the effect of the mercury is to render it as brittle as glass.

Cleaning up.—The cleaning up of the gold, mercury, and amalgam caught in a sluice is usually effected after every 6 or 7 days' run, though it is sometimes protracted to every 10 days, or even till the riffle-bars require replacing, the delay entailed by it being avoided as long as possible. Affording a light, half day's work, it is commonly reserved for Sundays. The first step necessary is to cease feeding in the pay-dirt and to let the water run through till it issues in a clean stream. Commencing then at the head of the sluice, 5 or 6 sets of riffle-bars are removed, and the dirt dislodged is washed down while the valuable metals lodge against the first remaining set of riffles, and are scraped out with a spoon and placed in a receptacle. The next half-dozen sets are treated in the same way, and thus the process continues to the end. Sometimes the riffles are removed more rapidly by taking up all save one at each 30 to 40 ft. The amalgam and mercury taken out must be pressed through buckskin or canvas, to remove the excess of mercury, which will run into a vessel placed to catch it. The remaining sponge-like mass of amalgam must be retorted to extract the gold.

Multiple sluices.—Among the modifications of box-sluices may be mentioned the double sluice. In this, the boxes or troughs are made of double the usual width, and divided by a longitudinal partition. They enable one section to be kept at work while the other is being cleaned up, and are useful where the supply of water is at some seasons sufficient for both channels and at others only for one. A modification of this, successfully adopted for the purpose of saving fine gold, is illustrated in Fig. 39. The plan consists in dividing the sluice at, say, the centre of its length, shifting the lower part on one side a distance of half its width, and placing another sluice of the same size beside it, so that the two "tail-sluices," as they may be called, cover equal parts of the lower end of the sluice. At the end of the single or head sluice, a grating *a* should be fixed, to prevent coarse gravel washing into the double or tail-sluices. The object is the division of the stream of water when it leaves the head-sluice into two equal parts, and spreading it over double the area of bottom board, so as to decrease its force, and thus lead to the saving of much of the fine and light gold, which is lost by the ordinary sluice. A further elaboration of the same idea is known as the "fantail-sluice" (see Fig. 39), wherein the tail-sluice is again sub-divided, a second grating *a* being placed at the junction, as before.

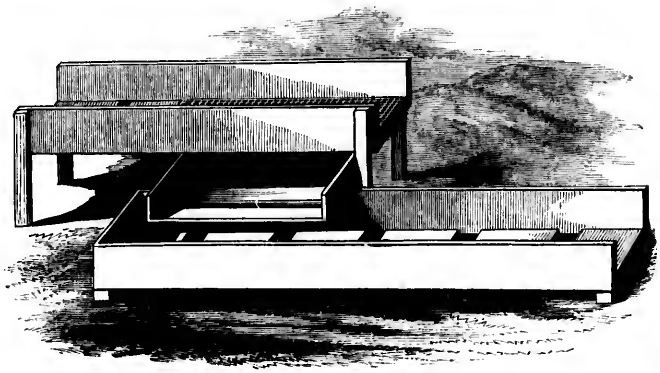
FIG. 39.



MULTIPLE SLUICES.

Under-current sluice.—An important apparatus, known as the "under-current" sluice, is represented in Fig. 40. The bottom of the last box of the sluice is partly covered with an iron grating, whilst underneath the grating another sluice is introduced, furnished with a fresh supply of water, and set at a lower grade. The end of the last box of the upper sluice being left open, all the large stones which will not pass readily through the grating are carried by their own impetus out of the sluice, and a pit or other accommodation must be provided for their disposal. The fine matters, together with a portion of the water, will fall through the grating into the under-sluice, where a low grade and consequently slow current causes the arrest of much fine gold that otherwise would have escaped.

FIG. 40.



UNDER-CURRENT SLUICE.

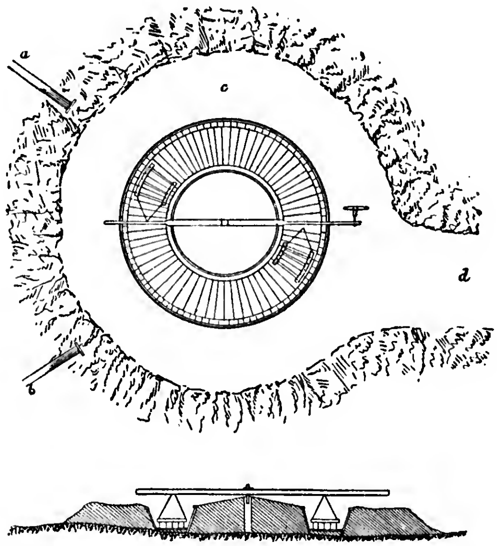
Evans and Frey's Sluice.—The sluice invented by Evans, and improved by Dr. Frey, of Sacramento, is made of cast iron, with transverse corrugations on the bottom, semicircular in shape, and 3 in. deep. At the bottom of each alternate corrugation is a narrow slit, through which the heavier material falls down into another riffle below, with larger corrugations. Both riffles are set on the same grade, which should be about 1 ft. in 12. The lower box is charged with mercury. These sluices are said not to cake, nor to require any attention beyond cleaning up once a week, while they are reputed to have stood the test of use below all other contrivances for saving gold.

Ground-sluice.—It sometimes happens that the amount of water available is not constantly sufficient for a box-sluice, but that a "head" can only be got for a short period, immediately subsequent to heavy rains. In such a case, it would not pay to erect a box-sluice; but recourse may be had to a ground-sluice, provided there is an abundant fall and outlet for the tailings. It also requires when working about six times as much water as the box-sluice to do the same amount of work. It consists simply of a gutter, formed partly by taking the stream through it, and assisted by loosening the earth with a pick. When the gutter has reached suitable dimensions, the pay-dirt is either washed in by the stream, or conveyed thither by manual labour. If the bottom be a hard and uneven bed-rock, its inequalities will suffice to arrest the gold; if not, a number of boulders too heavy to be moved by the stream must be thrown carelessly into the sluice. No mercury is used, no planking, and no riffles. It is never intended for continuous working, nor will it save any but the coarse gold. In order to clean up, the water is diverted from the channel, and the auriferous matters are collected, to be panned out, or washed through a cradle, tom, or short box-sluice.

Working results.—The amount of earth which can be washed through a box-sluice in a day per man employed will be limited by the capability of the men. When the height of the lift is 4½ to 5 ft., and 4 men are employed, 24 cub. yd. will be a good day's work, or say 6 yd. per man. With free earth, the tom may do as much; but it cannot exceed that figure, as the men are not able to lift more. In ground-sluicing, on the other hand, the quantity of water, character of the dirt, and inclination of the sluice, govern the result. Any number of men up to 6 may be employed, but the common numbers are 2 and 3. The quantity washed per man ranges between 20 and 50 yd. daily, the average being probably about 25 yd. per man per diem.

Puddling-machines.—As may be imagined, the machines hitherto described are quite unfitted for dealing with tenacious clay, which often occurs abundantly in alluvial formations, and is frequently highly auriferous. Special implements have therefore been devised for treating such gold-bearing clays, and these are known as puddling-machines. The original and most simple form is the puddling-box,—a rough wooden box about 6 ft. square and 18 in. deep; or even half a large barrel is commonly used, where operations are conducted on a small scale. Into this the clay is thrown, and supplied with plenty of water. The mixture is then stirred constantly with a shovel, prong, or rake, till the clay is thoroughly disintegrated and suspended in the water, when a plug inserted near the bottom of the tub is withdrawn, and the thin mud or rather muddy water is allowed to escape. A fresh supply of clay and water is now admitted, and the stirring process is repeated; this continues until the box has become filled with gravel, sand, &c., to the level of the plug-hole, when operations are suspended, and the deposit containing the gold, if there was any in the material treated, is taken out and washed up in a cradle or pan. Where operations are more extended, an upright shaft furnished with strong arms is placed in the centre of the tub, and set in motion by a mitre-wheel driven by horse- or steam-power. In California, puddling is seldom resorted to, because there is generally a sufficient head of water for hydraulicing, wherein the water force is so great as to break up the clay pretty effectually. In Australia, on the other hand, water is not so plentiful, and there the puddling-machine is in common use. The form is generally that shown in Fig. 41. It consists of a circular space, whose sides and bottom are lined with hard wood or iron, and in the centre of which revolves a perpendicular shaft worked by horse-power. From the cross-beam on this shaft depend two harrows, which are dragged round the circle, and puddle the dirt on their way. Sufficient water must of course be continually supplied. The gold and sandy matters collect at the bottom of the circle, and are removed at intervals and panned out. *a* is the water-supply drain; *b*, discharge drain; *c*, horse-walk; *d*, roadway. Occasionally steam is used in lieu of horse-power. On one occasion, a considerable quantity of silt

FIG. 41.



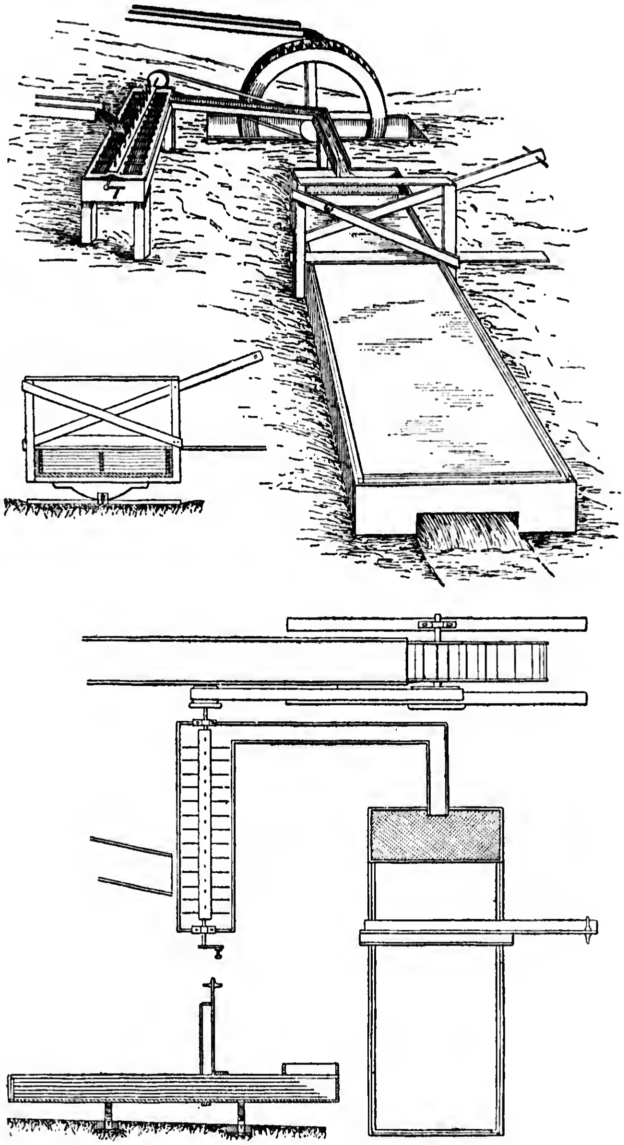
HORSE-POWER PUDDLING-MACHINE.

was taken out of a sludge-drain, and subjected to crushing and amalgamation; it yielded an average of nearly 2 dwt. per ton, which was considered by competent authorities to represent about the average loss from puddling-machines used at Sandhurst, an indication of the richness of the dirt.

Hart's patent cylinder puddling-machine.—This machine was so constructed that the stones and other refuse could be cleared away without disturbing the gold, which was cleaned up only once a week. For some reason, it never came into general use; but it probably suggested the idea of a cylindrical puddling-machine and sluice combined.

Combined cradle and puddling-machine.—Sketch, plan and sections of this machine are shown in Fig. 42. The necessary power is derived from an overshot water-wheel 8 ft. in diameter, which communicates with the puddling-shaft by two drums and a belt, and with the cradle by means

Fig. 42.



Combined Cradle and Puddling-Machine.

of a rod connected with a crank fixed at the other end of the puddling-shaft. The wash-dirt is thrown into the puddling-trough, which is supplied with water, and in which revolves an axle furnished with 25 iron arms. Hence the wash-dirt mixed with water flows into the hopper at the top end of the cradle. The bottom of this hopper is of sheet iron perforated with $\frac{3}{16}$-in. holes. In the cradle are 7 tiers of blanket-tables, made of $\frac{1}{2}$-in. pine boards, and varying in length so that each one receives its due proportion of sludge from the hopper. The blankets are washed 3 times a week, and the slime is concentrated in an ordinary small cradle, the gold being finally amalgamated. The plan and sections are drawn to a scale of 6 ft. = 1 in. The cradle has an inclination of 6 in., and an oscillation of 12 in.

Buddles.—These are very rarely used in placer-mining, though common enough in quartz-mining. They will be described in Chapter VI.

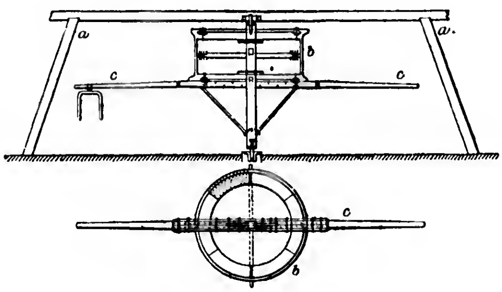
Whips and Whims.—Many contrivances are employed for raising earth from such depths as are beyond the limit of the level whence men can conveniently throw it out with shovels. One of the first means adopted in the earliest days of Australian gold-mining was that of erecting platforms or stages at convenient intervals, and the dirt was thrown from one up to the next by relays of men on each stage. Immediately succeeding this came the wooden windlass, a rude implement made entirely of wood.

Hand-whip.—This was soon followed by the German lever or hand-whip, an arrangement exactly resembling the *chadous* of Egypt, and already represented in Fig. 1, p. 9. It consists of a long, straight sapling, fastened by a rope to a rough post fixed vertically in the ground, or to a living tree if it be sufficiently near. This sapling is made fast at about the centre, and to its thin end is affixed a rope terminating in an iron hook for holding the bucket, while to the thick end is tied a log, or boulder, or bag of sand, sufficient to counterbalance the weight of a bucket of dirt. Two men are required, one filling the buckets below, while a second on the surface hauls them up as fast as they are filled. The weight on the thick end of the sapling enables him to do this with ease.

Horse-whip.—Whilst a variety of improvements were being made in the construction of windlasses, the horse-whip was introduced. In the most simple form, it consists of a post about 20 ft. long, fixed at an angle of about 45° to the ground, and firmly imbedded in it. The smaller end of the post should rise about 8 ft. above the centre of the mouth of the shaft. On this end is fixed an iron wheel or sheave, with a grooved circumference in which a rope runs. Another form consists of a set of legs with cross-logs on the top, and a pulley-wheel working on an axle fitted into the cross-logs, similar to the poppet-heads now in use. The rope passes over the pulley-wheel, and is made fast at one end to the harness, while the other is lowered down the shaft. The horse is then driven from the shaft along a road laid down for the purpose, till the bucket which had been hooked on to the rope at the end that was lowered into the shaft is raised to the proper height. When the bucket has been emptied, the rope is unhooked from the swingle-tree, the horse turned round, the rope hooked on to the horse's collar, and, as the horse walks towards the shaft, the bucket is lowered again. For the purpose of emptying the dirt from the bucket, a hook or pair of pincers, attached to a rope made fast to the framework, is inserted into a ring or band at the bottom of the bucket, which is raised nearly to the pulley-wheel for that purpose, and then, as the bucket is lowered by backing the horse, it is drawn aside from over the shaft, and as the rope by which it has been drawn up the shaft is slackened, the rope attached to the bottom of the bucket being tight, the bucket is capsized, and the contents shot into a barrow or truck placed to receive them; the bucket being emptied, the hooks or pincers are removed from the bottom, and it is lowered into the shaft again.

Water-power derrick.—Raymond mentions a curious water-power derrick, where "the power is transmitted more than 40 ft. by means of a rope from a small overshot wheel to the pulleys of the crane."

FIG. 43.



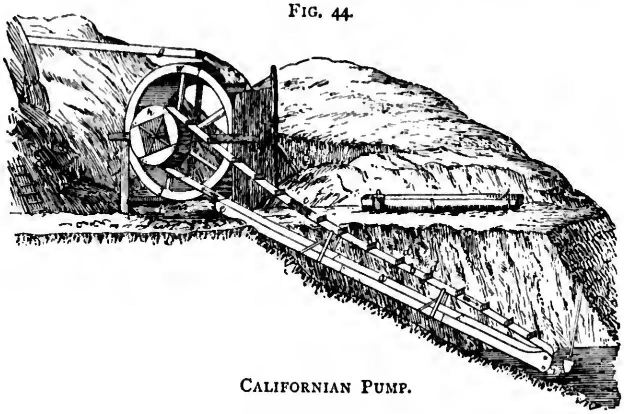
HORSE-WHIM.

Horse-whim.—This is represented in plan and section in Fig. 43. A strong framework *a* of timber holds in position a large drum *b* which works horizontally, and around which are wound the ropes attached to the buckets working in the shaft. Underneath the drum is a long beam *c*, with shafts to which the horses are harnessed.

Draining the workings.—The means which first suggested itself for getting rid of the water from alluvial diggings was as rude as the manner of raising the pay-dirt. Buckets, or skins looped up with iron rings, were either drawn up by hand or by the windlass. Two simple and effective methods have been much used where the configuration of the ground was suitable—the Californian pump, and syphons.

Californian pump.—The Californian pump is essentially a chain pump. A rectangular box, about 10 in. × 3 in. inside measurement, and varying from 10 to 30 ft. in length, according to need, is traversed by an endless flexible band or belt of canvas, on one side of which are securely fixed at intervals wooden discs nearly as large as the inside of the box. The lower end of the box is furnished with a roller, round which the belt passes, and is immersed in the water to be raised from the pit, while the upper end delivers the water into a trough or launder, by which it is carried away. At the upper end, the belt passes round a second roller or drum, which is made to revolve by either hand- or water-power. In Fig. 44 is shown one driven by a water-wheel: *a* is a flat wooden pipe or

Fig. 44.



Californian Pump.

box, open at both ends, forming the pump; *b*, the pump-belt, carrying the wooden stops, faced with leather, called the buckets or suckers *d*; *c*, the ends of the belt, joined together by lacing; *h*, the drum fixed on the axle of the water-wheel *w* and turning; *i*, entrance of water pumped up; *e*, exit of same; *f*, launder or race to convey the water from the pump and wheel clear of the working; *g*, a sluice-box set in a head-race to bring the water necessary for driving the wheel.

Chinese pump.—A modification of this pump, known as the "Chinese" pump, differs from it only in being made entirely of wood, the belt even being composed of short pieces of wood hinged together by wooden pins.

Syphons.—Syphons may often be used for draining the workings when it is not necessary to rise the water to a great height, and where the necessary fall for the delivery end can be had. Raymond describes one used in California of unusual dimensions. It was over 1000 ft. long and 4 in. in diameter. The pipe was made of No. 24 galvanized iron, in sections 30 in. long, riveted and soldered together. The water was raised 18 ft., and the outlet end had a fall of 40 ft., so that the delivery was

22 ft. lower than the inlet of the syphon. The two ends were fitted with 4-in. brass taps, which were closed when the syphon was to be filled. This operation was easily performed in about 2 hours by means of a 3-in. Douglas force-pump, throwing water in at the highest point through a vent-cock, by which also smaller quantities of water might be supplied from time to time to displace the air that gradually found its way in through leaks. An air-chamber at the bend was projected, but not found necessary, as by shutting the 4-in. traps at either end, it was easy to fill the syphons by means of the pump during the men's meal-hours. The flow was easily controlled by the taps, the lower or delivery-tap being usually left fully open, while the inlet-tap was partly closed. The velocity of the current was such as to carry out tons of coarse sand and gravel, some of the stones being as large as walnuts, and the sluice-boxes set at the usual slope were kept half full of water. There was no trouble in keeping the water within 2 in. of the inlet or receiving end, and this was plunged to within 5 in. of the bottom of the shaft.

Modes of working alluvial deposits.—The apparatus employed in recovering the gold from the wash-dirt has been already described; but it is also necessary to state that the manner of reaching the gold-bearing stratum or of raising the wash-dirt for treatment, is not in all cases alike, varying as may be dictated by the nature of the deposit. The essentially different methods are two—"Stripping," and working through "shafts" and "drives." Where the nature of the ground and the supply of water admit of it, hydraulicing is much cheaper then either; but that branch of mining is so important as to deserve a special chapter.

Stripping.—This mode of working must be adopted when the alluvial matters overlying the wash-dirt are soft and friable, or saturated with water from underground drainage. It consists in stripping off and taking away the whole of the non-auriferous superstratum, often having a depth of 20 to 30 ft., and thus laying bare the pay-dirt. Operations are begun by bringing a tail-race or drainage-channel up to the workings at such a level as to draw off the water from the bottom. This done, a "paddock" or patch is opened, the superincumbent earth removed and carted away and the layer of wash-dirt extracted and treated by sluicing, as already described, to separate the gold. The tail-race is carried on up the creek or washing, and carefully timbered, covered in, and protected, so that the waste earth may be thrown on it without fear of damage. Care must be taken to prevent floods, by means of dams to confine the water to a regular channel. Sometimes pumps and syphons will be necessary to keep the workings dry. The most advantageous plan is to fill the first paddock or space with the over-burden or refuse earth from the second, and so on; thus no part of it has to be removed any great distance, nor to be lifted to a considerable height. In one of the reports on gold-mining in

New South Wales, a shallow placer is mentioned which employs 70 men and 45 horses, besides 3 powerful engines. One of these last is engaged in hauling up trucks of wash-dirt to the sluice-boxes, a second in hauling up trucks of refuse to the tips, and the third in pumping. The trucks are hauled up by a wire rope on a tramway laid on an incline, and this application of the tramway has been found to secure an immense saving of labour.

Working by shafts and drives.—In many respects this is precisely similar to ordinary mining for any mineral—such as coal, for instance—a shaft being sunk on to the layer of pay-dirt, and tunnels or adits driven from the bottom along the deposit in all directions. This can only be done where the earth possesses a certain degree of stability. Generally, if not always, the shafts and adits require timbering, to keep loose earth and water from falling.

Slabbing a drift.—Difficulties may sometimes arise by the shaft tapping a drift or wet sandy stratum. The following plan was successfully adopted for dealing with a case of this kind on the Ballarat gold-field. The drift was cut away much larger than the proposed size of the shaft, slabs were then put in of the size of the shaft, and puddle-clay was thrown in and rammed down behind the slabs. In sinking deeper, however, a second drift was encountered, also containing much water, and this could not be overcome in the same manner as the first, on account of the impossibility of keeping the sand back while sinking through and putting in the puddle-clay. The following plan therefore was devised. Four slabs were fastened together in a square of smaller dimensions than the shaft, placed in the centre of it, and driven down into the drift; the last set of slabs in the solid ground above the drift were then removed, the walls of the shaft cut away a foot or more into the "country," and longer slabs fitted in the place of those which had been taken out. The shaft was then cut down of the increased size and slabbed, the four small slabs in the centre being always kept below the lowest set of long slabs, and the drift between the box of short slabs and slabbed sides of the shaft only being removed so as to make room for the slabs until the set had been placed in position and made fast. The drift between the box in the centre and the long slabs was then taken out, the box lowered, and the same process followed with each set of slabs, until they got through the drift into solid ground again. They then commenced to slab upwards from the bottom with slabs the proper size of the shaft, and as each set was put in, puddle-clay was filled in behind, and rammed down, the long slabs, called "drift"-slabs, keeping back the drift. When completed, the shaft was the same size all the way down, and there was a wall of puddle-clay between the double sets of slabs, extending a foot or more above, and the same distance below the drift. This was generally effectual in stopping back the water, but in some cases it forced a passage through, and recourse was then had to caulking the seams between the slabs. These last were split, and at first were fitted into sets by notching the ends; but this plan was not suitable in wet ground, and gave way to that of boring holes through the ends of the side-slabs with an auger, and driving pegs in to keep the end-slabs in position. Instead of caulking the leaks, plugging was sometimes resorted to. This was managed by boring holes through the slabs with an auger, and then forcing through plugs of puddle-clay, prepared and rolled to suit the size of the holes, by means of a rammer, until it was impossible to force any more, or the leak was stopped.

Piling.—Another plan sometimes followed is that known as "piling." The shaft is "opened out," as already described, a little above the drift, a frame is made having nearly the same dimensions as the shaft where opened out, or enlarged and placed in the latter, and slabs pointed at one end are then driven down behind this frame as far as possible into the drift immediately below. Sinking is then continued in the drift, always keeping the points of the slabs driven into the drift below the spot where sinking is going on. When deep enough, another frame is put in to support the lower ends of the slabs against the inward pressure of the drift, and the next set of slabs are then driven down between the second frame and the lower ends of the first set of slabs, and so on throughout till the solid ground is reached again. The slabs thus driven are called "piles." Sometimes, when sinking through such a drift, a box is driven down in the centre of the shaft, which helps to support the points of the slabs against being forced into the shaft. The greatest difficulty is occasionally experienced in keeping the frames in position, because the pressure from the drift may not always be equal on all sides, and consequently the frames and piles may be carried out of plumb; and now and then the drift will burst into the shaft from one side or the other, in spite of all precautions. As fast as this is removed, to enable the men to make good the timbering, more may run in, so that a large cavity is made on one side, and, the pressure against the frames being unequal, may even twist them half-way round. Despite the twist, it is possible in some cases to continue sinking to the firm ground by filling up the cavity with bark, clay, and other materials, then, having drained the water from the drift to some extent, but before puddling up so far, the shaft may be repaired so that the slabbing and puddling up may proceed in such a manner that the shaft may be plumb when finished. In other cases it may not be possible to stop the running-in of the drift, nor to repair the damage done to the timbering; then the shaft may be filled up with earth to the level of the top of the drift, and a fresh sinking commenced from that point, taking out the old timber where necessary as the descent progresses. When the solid ground is reached, the slabbing and puddling up may be carried on as already indicated.

Drawing slabs.—For the purpose of taking out the slabs from a shaft which it is no longer intended to use, a stage is made to suit the shape of the shaft, and small enough to be raised or lowered inside the slabbing of the shaft. This is lowered into the shaft by ropes, and secured. A man is then let down the shaft by a windlass, and as fast as he draws out the slabs he sends them up by it. As soon as a few sets have been drawn out, the stage must be raised level with or above the top of the space from which the slabs have been drawn, so that in case of the sides thus left falling in, the earth might descend into the shaft below the stage.

Iron cylinders in lieu of slabs.—In consequence of the difficulty met with in sinking a shaft by the ordinary means through an unusually troublesome drift, the idea was conceived of using sheet iron instead of wooden slabs. It was formed into large cylinders the size of the shaft, the latter was cut down to the proper size, and the cylinders were let down one above another, with the intention, when the drift was reached, of forcing the cylinders into the drift in advance of the sinking; and it was reckoned that, by keeping the cylinders well driven down below the point at which sinking was proceeding, the drift would be prevented from running into the shaft. The cylinders answered very well in sinking through the solid ground so long as they had sufficient play; but when the clay began to swell, they became fixed and could not be forced down. Cylinders were then prepared of less diameter, and let down inside of those which had become fixed, and thus a depth of about 30 ft. was reached; but where great pressure came against the sheet iron it buckled, and wrought iron would not stand the pressure necessary to force it through a drift.

Boxing.—Where the material overlying the wash-dirt is of a loose nature, it will be necessary to slab the drives or adits much in the same manner as the shafts. This operation is termed "boxing" in Victoria. "Sets of timber," or legs and caps fitted together by means of grooves in the cap-piece and shoulders on the legs, are commonly used.

Paddocks and paddocking.—It has already been explained that the term "paddock" is applied to a patch of wash-dirt lying *in situ.* It has also another meaning. Sometimes, instead of washing the pay-dirt from a digging as fast as it is raised, the miners stack it in "paddocks," which are spaces alongside the shaft strongly fenced in with slabs, until the claim or property is exhausted, and then hold a general washing up. This system of working is called "paddocking."

Working Reef-washes.—In the case of reef-washes or benches, the alluvial wash-dirt may lie 300 or 400 ft. above the present level of the stream, to which it must be conveyed for treatment. A simple method of transporting it is described by Ben. B. Spargo, of Snowy Creek, Victoria, in a letter to the author, and consists in shooting it in green hide bags down sawn timber shoots.

Sluicing.—The advantages of sluicing an alluvial deposit are manifestly great, as when once the races or water-channels are made, very little labour is required for carrying on the work. Under varying conditions, there will be varying results. In one instance, 6 men have been able to sluice away an acre a fortnight; in another, 8 men got through an acre a month. The following principles are recommended to be observed when it is intended to sluice away the whole length, breadth and depth of an auriferous deposit :—

1. To get a proper and sufficient fall in the tail-races (or channels for carrying off the light particles of waste materials) for boxes of large dimensions.

2. To have a large flow of water to keep the tail-race clear and in working order.

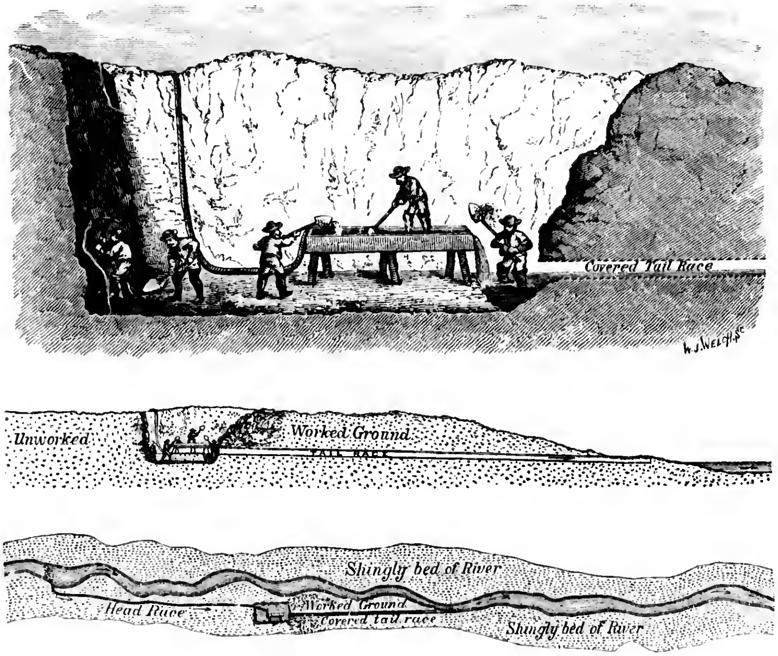
3. To have small wash which will easily run off, and to strip the ground by water-power. Wherever this can be accomplished, a very small amount of gold will leave a profit.

Water-soaked flats can only be worked by a tail-race with sufficient fall and large boxes thoroughly draining the ground. Sometimes these tail-races have a very low grade or inclination. An important one alluded to in the reports on the New Zealand gold-fields was carried for 8 miles at a grade of 1 in 62·11, and was then continued for some reason at 1 in 59·2; this alteration in the grade is very questionably wise, as the ordinary experience of miners is that if a tail-race starts with a quick fall and becomes flatter as it advances, it is very liable to choke at the lower end.

Covered tail-races.—For the following description and illustrations of the method of working with covered tail-races, first practised by the Chinese at Kyeburn, and since adopted by some Europeans, the author is deeply indebted to H. W. Robinson, Warden of the Mount Ida division of the Otago gold-field, New Zealand.

The Kyeburn river is a mountain stream, ordinarily of no great volume, that finds its way through a shingly bed filling the channel. It is subject to heavy floods, which come on with great suddenness but subside as quickly. The ordinary state of the river is that of a smallish stream of water meandering at a rapid pace through a wide expanse of shingly gravel. At a depth of a few ft. below the surface of this gravel bed is a rather more compact layer of similar gravel, in which gold is thinly distributed. The problem was how to work this auriferous layer to advantage. When an open pit, called by miners a "paddock," was sunk in the shingle below the level of the flowing stream, the water filtering through the loose gravel quickly filled it up. It was possible to keep the water under by baling or pumping, but both these modes were too expensive. Tail-races, that is to say, open ditches carried through the shingle down the river, would drain the excavations, but these were

Fig. 45.



Sluicing through Covered Tail-Races.

liable to be lost at any moment, as whenever a flood came down they would be filled up and obliterated. To remedy these difficulties, the plan was devised of bringing up a tail-race to drain a paddock, to build it carefully as a covered drain, and to fill in the loose shingle over it at once, thus securing it from damage by floods. The method will be better understood by reference to Fig. 45.

The gravel is thrown into a sluice-box, to one end of which water is conducted by hose or otherwise. The force of the water carries it along. A man on the box keeps it stirred with a sluice-fork, and throws out all stones large enough to be lifted by the fork. At the end is a slight drop, where another man with a shovel is constantly employed lifting the finer gravel, and only what the water can hold in solution or suspension escapes down the tail-race. The tail-race is lengthened as the workings proceed up the course of the river, all débris being heaped over it. The paddock is constantly moving up. All gold is saved in the sluice-box only. The tail-race is simply a drain.

Dry washing.—This somewhat contradictory term is applied to processes for separating the gold from the dirt without the aid of water. One is practised, principally by Mexicans and Indians in the Western States of America, where a supply of the liquid element is unobtainable. Only the richest pay-dirt is treated by this process, which is conducted as follows. The dirt is spread on a raw hide, and allowed to become perfectly dry; next it is powdered up by rubbing it with the hands, and all the larger pebbles and bits of stone are picked out and cast away. The residue is then placed in a *batea*, already described, and the lighter particles of base matters are winnowed from the gold by tossing the contents repeatedly into the air with a circular motion, which enables the wind to disperse the light bodies while the heavier gold falls back into the *batea*. When this has been continued till the heavy residuum consists largely of the precious metal, the purification is completed by blowing, which process has been alluded to on a previous page. When two men or more are working in company, a hide or blanket may be used for the winnowing. Nothing but very rich stuff can be worked remuneratively by this system, and the miner never goes very much deeper than his own height in search of the pay-dirt. Frequently, instead of stripping off the worthless overburden or overlying stratum of earth, he sinks a little shaft or pit about 6 to 8 ft. deep, and then drives or burrows on the wash-dirt beneath. This system of working is known in America as "coyoting," from the resemblance of the diggings to the underground houses of the coyote, and is not always confined to the operations of the dry-washing miner.

Quite recently a new form of winnowing-machine for separating gold from sand, called the "Eureka concentrator," has been introduced for working dry placers, which cover a boundless area in Tropical America, Australia, Siberia, &c. It weighs about 250 lb., and measures 3 ft. by 4 ft. by 4 ft. The ore-table is stationary, not having a side or end shake of any kind. Under it, is a peculiar double-acting bellows, which forces a pulsating blast of air up through the canvas, which, on top of a wire frame, forms the ore-table. Riffles are formed on this inclined table to catch the heavier particles. A peculiar and valuable feature of the appliance is an apparatus which keeps the coarser gravel, &c., moving on downward to the discharge end. The machine is constructed to stand the dry hot winds of Arizona and New Mexico, and has no leather or boards used in its construction. By simple means, feed- and tailing-elevators are attached, by which the hopper is fed with the sand or gravel, and the tailings are removed out of the way. With these attached, a mule or horse runs the machine, doing the work of 3 men. The No. 1 machine is equal to 40 in. of water in sluices, and works dirt as cheaply as sluicing with water at 2½c. (1¼*d.*) an in. Light machines are made for a man to run by hand. The apparatus works very rapidly, and has a capacity of 3 tons per hour. Ordinary placer-gold is readily caught in its riffles. The concentrator is quite simple in construction, not liable to get out of order, is well adapted for its work. More or less blast can be given to work heavier or lighter stuffs. A hard graphite lubricator is used on the journals, and is applied in a peculiar way. This is of great advantage in hot climates, where ordinary lubricators do not answer. There are in these countries thousands of acres of ground which cannot be worked except with machines of this kind, but which can be made available when worked dry.

The *Colonies and India*, of June 2, 1882, records that the Mines Department of New South Wales "has tried a new dry-blowing machine imported from California. About 4 dwt. of gold was mixed with 50 lb. of earth; in 3 minutes the dirt was fanned off, and it was then found that less than 1 gr. of gold was lost. This machine will be very valuable in places where water is scarce."

Other forms of apparatus have been introduced, in which mercury plays an important part. The one which has been most prominently before the public operates by throwing the auriferous material by centrifugal force against a wall of mercury (why not amalgamated plates?). The material is placed in a sort of hopper, from whose taper end it is allowed to pour between two curved copper plates, situated horizontally, and revolved at a speed of 65 to 80 revolutions a minute. Passing between these plates, the sand is driven by centrifugal force against a "wall" of mercury, which is also maintained through the action of centrifugal force. Surrounding the copper plates is an iron casting like an enormous stew-pan, with the greater part of the bottom cut out, so that its half section resembles a letter L. This is connected with an axis by 4 hollow arms, each of which is made to contain about 50 lb. of mercury. The whole arrangement is revolved in a direction contrary to that of the plates, and, by the rotary force, the mercury runs from the arms through grooves provided, and climbs along the upright surface, corresponding with the upright stroke of the L, thus forming a perfect wall. Every particle of gold as it is thrown against this wall instantly amalgamates with it, while the sand is partly thrown off by its own rebound and partly blown away by a series of pipes attached to a blower used in connection with the machine. When whatever quantity of sand the operator chooses is passed through, the machine is stopped, the mercury is withdrawn by a tap from the arms, into which it falls the instant the rotation ceases. The operation results in the recovery of the gold without sensible loss, and the advantages claimed for the plan are :—(1) that it extracts every particle of gold from the matter passed through it, and (2) that it does so without serious loss of mercury. It is claimed that it will render it possible to work over again with profit the "tailings" of mines operated under old systems.

There is no available information as to the working cost of any of these methods. Their success depends entirely upon their ability to perform the necessary operation on a large scale at a cost not exceeding 2½*d.* to 5*d.* a ton.

River-mining.—There are two distinct kinds of river-mining, one being prosecuted by emptying the river-bed of its water before commencing operations, the other conducted while the river is in the occupation of its bed. The former consists in turning the stream out of its course by means of a dam into a new channel, which may be either a ditch cut in the ground, or a wooden flume. Of course, only small brooks and rivulets can be treated in this way, and the working even in them can only be carried on with safety during the dry season, when the water is low and not liable to sudden flooding, as a freshet might carry away tools and implements, and undo all that the miner had done, in a very short time. Moreover the little tributary streams from the hills, which come in on every hand, give a deal of trouble, and necessitate pumping. Arrangements must also be provided for removing the huge boulders which often encumber the bed of a stream, and hide much of the gold. The pay-dirt is excavated and run through a sluice to extract the gold. The drawbacks and risks connected with this kind of mining have to be taken into consideration, but it has sometimes yielded very remunerative results. In California, the rich river-bars have been all but exhausted; yet as late as 1875, some Chinese were washing the banks and bars of the Yuba river in this way, and making it pay, though the same ground had already been worked three or four times by whites. Fig. 46 illustrates the river claim of Trent, Diamante & Co., alluded to on p. 573, which is worked in this manner; further details will be found on the page indicated. Guinness speaks of the plan as being most successfully used when reaches of some extent and of small depth occur, and when only a moderate depth of shingle overlies the solid rock forming the bed of the river. Considerable areas may sometimes be made available by cutting a new channel through an isthmus, and working the bed of the bend thus laid bare.

Lifting rivers.—A plan known as "river lifting" is practised in British Columbia. It is applicable to streams not exceeding 10 to 15 ft.

wide and 2 ft. deep, and consists in providing a temporary artificial bed for the stream to flow over while the actual bed is being worked out. Two essential conditions are,—an abundant and cheap supply of timber, and an adequate fall in the stream. The first step is to drive stout piles into the ground on both sides and in the centre of the stream at a few ft. apart, joining the members of each side row by means of stout quartering spiked to their upper part. Joists are then laid across the river with their ends resting on the lateral bars, so that each triplet of piles is

Fig. 46.

Draining a River Claim by Californian Pump.

joined transversely. Next, planking is nailed on the transverse bars inside the piles and carried up to the tops of the piles themselves, forming a wooden sluice or launder just above (say 2 or 3 in.) the stream, and of a capacity to accommodate the stream. When the sluice, which may be $\frac{1}{2}$ or $\frac{3}{4}$ mile long, is complete, the river is lifted into it in the following way. At the upper or inlet end of the sluice, the stream is gradually dammed by driving piles in so that their heads are flush with the floor of the sluice. The piles should be commenced with spaces between, and these gradually filled up, so as not to concentrate the stream into one narrow channel. As soon as the damming is completed, the stream, unable to flow in its old bed, gradually rises till it enters the sluice, and then, if the fall is sufficient, it fills the sluice and flows bodily through it. While the river occupies the sluice, the bed is worked out and cradled or sluiced. In case of a freshet occurring, the damming piles may be pulled up and the stream allowed to re-occupy its bed, thus reducing the risk of having the sluice destroyed. This does not prevent the dam being reconstructed and work resumed when the freshet is over.

The banks of the creek or stream must be sufficiently steep to prevent the water running away in a lateral direction; when this is not the case, the stream has to be banked in for some distance above the dam.

Atmospheric Cylinders.—Another plan of removing the water from the bed to be worked is by means of atmospheric cylinders. This system is described by Warden Allen, of Picton, as follows. "The cylinders are large enough for a man to work in. They are made in lengths, the length used depending upon the depth of the river. A powerful air-pump is attached to the apparatus, and air is forced into the cylinders when they are placed in the river. The air forces out the water, and the man in the cylinder is able to collect the drift for washing. I am told it is very trying work for the men. Dredges would answer better."

Subsequently, Warden Allen kindly furnished the following additional particulars. "I am inclined to think that the apparatus is useless for all practical mining purposes, excepting probably prospecting shingle beds of shallow rivers. I am informed as follows.

"That the apparatus consists of 2 powerful air-pumps, a sufficient quantity of indiarubber tubing, and iron cylinder in lengths of about 3 or 4 ft. each, and a crane and windlass for raising and lowering the cylinder into the river. The cylinder is composed at the top of an air-tight compartment about 5 or 6 ft. high, of the same diameter as the cylinder (about 3 ft.); to this upper compartment the tubes connected with the air-pumps are attached, and there is an escape-valve to allow the air to escape when the pressure is found too great. On the floor of this upper compartment is a man-hole that can be opened and closed at any time, and of course must be so fitted as to be water-tight. To this upper compartment the workmen can affix by rivets as many lengths of iron cylinder as they require, according to the depth of the river. These lengths of cylinder are simply plain iron tubes, about 4 or 5 ft. long and 3 ft. in diameter. When a sufficient length of cylinder has been attached to the upper compartment, the apparatus is lowered into the river and rests upon the bottom. The men who are to work enter the upper compartment through a man-hole in the side or top, and the lid is replaced and fastened by screw-bolts so as to make the compartment water-tight. The inner man-hole in the floor is then opened, and air is pumped into the cylinder in sufficient quantity to force out the water in the cylinder, and leave the bottom of the cylinder as nearly as possible free from water. One man descends, and a bucket fixed to a block and tackle inside the upper compartment is also lowered. The man below fills this bucket with the wash-dirt (gravel or mud), and it is hoisted up to the upper compartment. When sufficient dirt has been raised, the apparatus is drawn up, and the proceeds are landed to be cradled or cleaned up in any way adopted by the parties at work. The escape-valve in the upper compartment previously mentioned is used as a regulator to protect the men at work, for too great a pressure of air would cause serious consequences to them.

"As I before informed you, the apparatus has not been at work for many months, in fact has not been properly tried, and is not likely to be used now, for a new company has been formed to divert the course of the river, and work the ground in the ordinary manner, and this apparatus is to be set aside. I am inclined to think it would not pay any company to work this atmospheric cylinder."

Dredging.—Rivers proper cannot, of course, be turned in this way, as the expense and risk would be greatly magnified; they are, however, worked by dredging up the bed without disturbing the course of the water. Dredges built much after the fashion of harbour-dredges, and driven by a current-wheel, have been used for a long time and with considerable success, especially in New Zealand, where one at work on the Clutha river yielded 4*l.* a week each to 4 men for over 5 years; but they are liable in a certain degree to be interfered with by floods, they cannot work in eddies (where the gold is largely deposited), and their effective capacity is limited.

Warden Allen, of Picton, to whom the author is indebted for many kindnesses, sends the following account. "I have obtained from Mr. Warden Carew, of Lawrence, the following description of the dredges used in the Molyneux and Clutha district.

"There are three water-power wheel-dredges on the river, answering admirably, and giving very good returns. So far as I can learn, these dredges are on the ladder and bucket principle; 25 buckets and sometimes more, according to the length of the ladder used, are mechanically connected by a heavy link chain revolving round a series of rollers attached to the ladder, acting as auxiliaries to two large tumblers, the heaviest of which, weighing 6 cwt., is attached to the bottom end of the ladder, round which the buckets revolve, and carry up the auriferous gravel. The tumbler at the top of the ladder discharges the gravel into a shoot emptying into a cradle rocked by hand. This primitive method for saving the gold could in my opinion be easily improved upon by means of excentric wheels to suit the different strengths of the current, putting a series of shaking tables in motion, say, one with a contra action to the other. If this system of saving gold could be adopted, and I can see no reason why it should not, it would in my opinion be a much more economical method, dispose of more gravel, and save a great deal more gold.

"These dredges can raise 100 to 160 tons of gravel in 24 hours, and the depth of water in which they can work is 4 to 12 ft.; length of ladder, about 37 ft. The greatest depth in which they can work in ordinary currents is about 20 ft.

"The average strength of the current is about 6 knots an hour by the log, but the dredges can work with greater safety and more regularity in a 3-knot current.

"I believe these dredges are the most suitable for this river, as the gold principally is obtained in the current, and there is little or no gold where the river is sluggish; 5 gr. of gold per ton will pay good wages, and there are miles of such ground in the river. Although there are some rich patches, there is no regular or distinct 'run' of gold. Generally the gold is sparsely disseminated through the gravel. (The foregoing description was obtained by Mr. Warden Carew from Mr. Nicholson.)

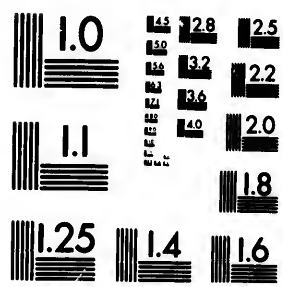
"Mr. Carew adds as follows. In addition to the information he has given, I may add that a dredge is formed with two flat-bottomed boats, each of about 12 tons, and that the ladder upon which the buckets revolve is fixed between the two boats. The buckets are made of iron, steel-tipped, and lift 1 to 1½ cwt. each. There are 4 current-wheel dredges in the river, besides two steam-dredges of 25 and 22 tons (ordinary small steam-boats specially fitted up for dredging), and there are two new dredges being built, one of iron, and it is said will be fitted with a different kind of machinery, costing when complete about 6000*l*.

"The larger of the 2 steam-dredges now working is 10 horse-power, lifts 50 tons of drift per hour, and puts it through the cradle. The cradle is 13 ft. 6 in. long by 4 ft. 6 in. wide, and in addition has wide sluice-boxes from tail of cradle to the water. This boat has not been long in operation, but the miners estimate that when fairly at work in a good position 1 gr. of gold per ton will pay."

Dredges working by steam-power possess manifest advantages in being independent of the current; but even with them, a great impediment has proved to be that the least flood in the river brings down an immense quantity of tailings and other débris, which fill up the dredging-buckets to the exclusion of the much more highly auriferous older deposits on the bottom.

Vacuum-dredges.—These are of many forms, varying chiefly in the

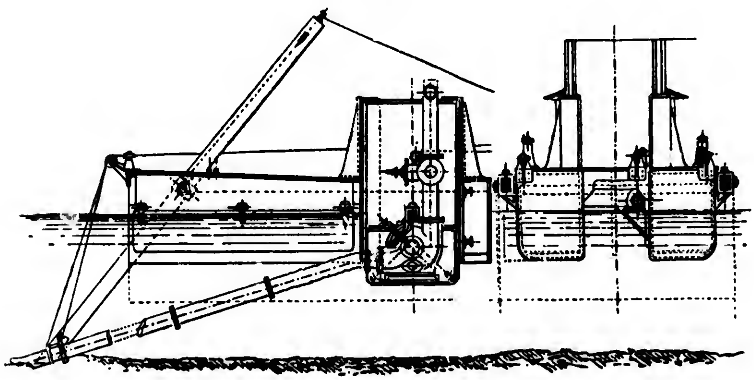
IMAGE EVALUATION
TEST TARGET (MT-3)



6"

means adopted for producing the necessary vacuum. The Bazin dredge was one of the first worked on this principle. In it the buckets necessary for ordinary dredging are replaced by a simple tube. The principle upon which the vacuum is produced may be illustrated thus. Suppose an empty vessel, say a ship's hull, to be immersed in a body of water, either by its own weight or by weight applied to it, so that there is a difference of level between the water outside and the bottom of the hull, and suppose now a hole to be opened in the bottom of the hull, there will immediately be an inrush of water. But suppose the hole to be prolonged by a pipe just reaching to the bed on which the water rests, it will be the lowest layers of water that will find their way up the pipe, and if the pressure around be sufficient, the speed or force will be such that some portions of the subjacent soil will be carried along with the water. But this process would soon defeat itself by filling the hull. This is easily avoided, however. A specially constructed centrifugal pump is so adjusted to the

FIG. 47.



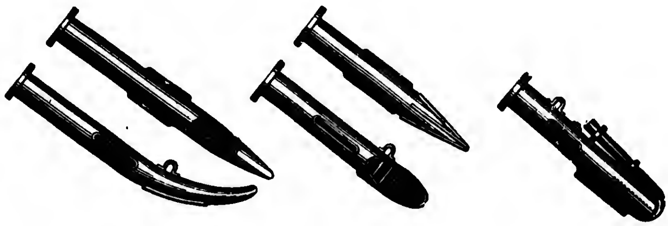
BAZIN DREDGE.

apparatus that, without break of journey, it receives all the matters which are forced into the tube, and, adding fresh impulse to their progress, delivers them over the side of the hull. Its construction is shown in Fig. 47.

It was first used for clearing silted-up wrecks in the Bay of Biscay, in 12 to 16 fathoms of water. One used at the Leith Docks was said to put 76 tons of sand on board in 45 minutes, or about 100 tons per hour, while the prime cost was less than one third of that of ordinary dredging apparatus. It soon became evident that this machine might be applied to raising auriferous dirt from river-beds. One set to work "on the

Feather river, in Maine," is fixed on a boat 90 ft. long and 20 ft. wide. The deck is about 3 ft. above the water-level, and on it is a house where the workmen eat and sleep. A 12-H.P. engine hoists and lowers the tube or cylinder by means of pulleys fixed to a common derrick. Running along the side of the boat, and fastened securely to it, is an ordinary flume, 100 ft. long by 20 in. wide, provided with the usual appliances for catching the gold. At the upper end is a pump worked by steam, that pours a constant stream of 100 miners' in. of water into the flume. The quantity of earth taken up is about 300 tons in 10 hours, and it is said that more could be brought up, but no more can be washed in the present sluices with the amount of water used. The work has been carried on in water running 6 to 16 ft. deep. Of course the only difference necessitated by the greater depth is an increased length in the cylinder or tube.

FIG. 48.



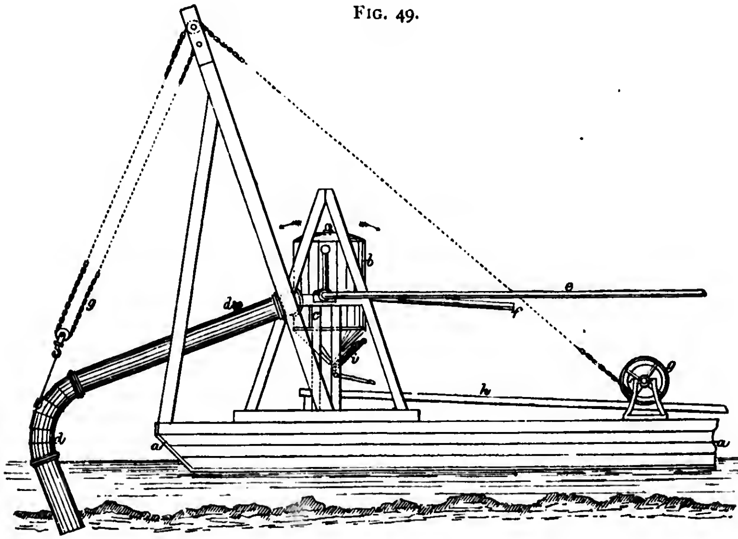
NOZZLES FOR VACUUM-DREDGES.

The gravel is so thoroughly pulverized that all the gold is said to be washed in a very short sluice. Several forms of nozzle are used, according to the nature of the bed, as shown in Fig. 48.

A disadvantage of this form of dredge is that it requires a considerable depth of water in order to produce the requisite amount of vacuum for efficient work. This has led to the introduction of steam-vacuum dredges of various forms, the most successful of which is shown in Fig. 49, and is at work on the Fraser river, British Columbia, the Snake river, Idaho, and on several Brazilian streams. The apparatus is placed on the deck of a flat boat or scow *a*, 80 to 100 ft. long and about 30 ft. wide. Atmospheric pressure governs the operation of the apparatus. This pressure being about 15 ft. to the sq. in. the force with which a column of water and gravel is driven up the draught-pipe can be readily computed: an 8-in. pipe has an end area of about 50 sq. in.; in such a pipe, therefore, the pressure up the tube is 750 lb.; for a 12-in. pipe, the force would be 1700 lb.; for an 18-in. pipe, 3800 lb.; and for a 24-in. pipe, 6700 lb. The principal parts of the machine are a vacuum-chamber *b c*, which rests on hollow trunnions *c*, upon which it oscillates, and through which steam (*e*) and water (*f*) connections with the top and upper part of the vacuum-chamber are made; a draught-pipe *d*, which rests on the bottom, and through which the solid material is brought up into the vacuum-chamber; and a water-gate below the water-line in the draught-pipe, through which water is admitted when desired.

Upon the dredge-boat is also a boiler-house containing a boiler and steam-pump, each connected with the vacuum-chamber. A winch or

FIG. 49.



STEAM-VACUUM DREDGE.

hoisting-engine *g*, for raising and lowering the draught-pipe, and a long sluice *h* to receive the contents of the vacuum-chamber and wash out the gold, complete the equipment.

To operate the machine, the draught-pipe is lowered until its open end rests upon the bottom. Steam is then let into the vacuum-chamber, expelling the air through the air-valve. The air-valve is then closed, and a jet of water is forced upon a perforated disc in the upper part of the vacuum-chamber, condensing the steam and forming a vacuum, into which the water at the bottom of the draught-pipe instantly rushes, carrying with it gravel, sand, stones, or whatever else may be at the end of the pipe; and as these pass up and into the vacuum-chamber, the pipe burrows into the bottom, the vacuum-chamber swinging slightly forward on its trunnions as the pipe goes down. The suction is even capable of dislodging gold from pot-holes in the bed-rock.

A delivery-door *i* at the bottom of the chamber is instantly opened by means of a cam-lever, and the contents fall into the sluice. The delivery-door is then closed, the chamber filled with steam as before, the steam condensed, and another load of solid material brought up; and this operation is repeated as often as may be desired, 1 to 5 tons of gravel, &c., being raised every 5 minutes, varying with the size of the vacuum-chamber and draught-pipe.

That nothing may become lodged in the pipe, it is made smaller at the lower end, and whatever enters there readily passes up into the chamber. Another excellent feature is the method of introducing the steam and water. The pipes by which these enter the vacuum-chamber proceed from the upper side of the hollow trunnions. The steam-pipe from the boiler enters the end of one of the trunnions by a packed, steam-tight joint, and the cold-water pipe enters the other trunnion in the same manner, thus allowing the chamber to swing freely on the trunnions, and at the same time doing away with flexible pipes. The extreme simplicity of this dredge also commends it. There are no complicated or delicate parts to get out of order; it is easily operated, requiring only 4 or 5 men upon the dredge-boat; and the entire working expense will not exceed $20 or $25 (4 or 5*l.*) per diem.

Inquiries concerning the working of this apparatus, addressed by the author to Professors J. D. Hague, R. W. Raymond, and W. A Skidmore, elicited the following remarks. "As regards any gold-bearing rivers in Maine, you are in error. There is no such river in that state. A machine on this principle was used at Oroville, on the Feather river of California, a few years since. Skidmore saw the machine in operation at Oroville, Butte co., at that time, and thinks that if there had been any coarse gold or nuggets in the matter raised, it would have brought them to the sluice-box. He happened to have smelted the resulting gold, and found the nett proceeds to be about $16 50c., after an expenditure of $100,000. As a gold-mining appliance under the conditions of our streams (gorged with tailings to a depth of 20 or more ft.), it must and did prove a failure, for reasons too obvious to enumerate; but he thinks that under conditions which may be imagined, but which are never found to exist, it would prove a success, viz. given a virgin river bottom, with 6 to 10 ft. of gold-bearing gravel on the bed-rock (averaging about $3 per cub. yd.), and with water enough to float the scow and her machinery. We have no such streams here, and it may be said that here at least it is a practical failure."

Beach-mining or beach-combing.—On the Pacific shores of America, extending in patches for a considerable distance (see pp. 151–3), are a number of auriferous deposits, known as "ocean-placers." Similar formations exist also in New Zealand (see pp. 526, 570). The beach sands contain minute scales of gold and platinum, and a large percentage of magnetic iron or black sand, intermixed with the common beach sand, composed principally of quartz. The gold occurs in sufficient quantities to make mining for it remunerative at certain places. In beach-mining, considerable aid is derived from the natural causes at work—the winds, tides, and surf,—which act as a natural separator in parting the light and useless from the heavy and valuable particles. The force of the wind drives heavy swells upon the beach at high tide, and with them a certain amount of sandy matters; while at the ebb of the tide, the surf lashes the beach and carries back the light portions of the mass with the undertow, leaving some of the iron-sand, gold, and platinum, whose greater specific gravity enables them to resist the force. At low water, the miners go down on the beach and scrape up the iron-sand, which is generally left in thin layers, stacking it back from the reach of the surf, and subsequently washing out the gold. The position of the sands is liable to be changed at every tide, so that a fresh survey has to be made each day before commencing operations. When the richest spot has been chosen, mules laden with empty *alforjas* or raw-hide sacks are led down to it at low water, and the most specious-looking portions are hastily gathered for treatment at leisure, a couple of days often sufficing to wash the harvest of a month. For a long time, the common mode of washing was with a small stream of water in a sluice, terminating on an apron or tom, with turned up sides and ends, the bottom perforated with small holes, and underneath a wooden box set slightly sloping, and floored with a covering of amalgamated sheet copper. The auriferous sand is washed upon the apron, and, passing through the small holes, strikes vertically upon the copper below, the gold adhering to the copper, while the worthless sand passes off through an opening in the lower end of the box. This process is manifestly imperfect, as all the gold that does not instantly adhere to the copper is washed off and lost. As the particles of magnetic oxide are very nearly of the average diameter of the gold-particles, and are moreover rounded, whereas the gold is scaly, the great difference in their specific gravity (say 5 : 19) has really but little influence on their separation.

The ordinary blanket-sluice, or a combination of amalgamated copper plates, riffles, hanging-plates, &c., such as the Russel amalgamator, were for a long time relied on for catching the gold. But when the miners assayed their tailings, they found that in most cases fully ⅘ of the gold had been lost in the treatment. Not only was the separation based on a difference of specific gravity quite unavailing, but examination showed that the gold-specks were coated with "rust," which prevented amalgamation. Experiments were then instituted on all hands. Chlorination and other chemical processes were found too expensive, but confirmed the richness of the sand, showing that much of it was worth 2*l.* to 6*l.* per ton, and some a great deal more. The quantity yielding 1*l.* to 2*l.* per ton is said to be practically inexhaustible. A company owning a large extent of these diggings is reported to have elaborated a process (Sublett's) capable of saving 90 per cent. of the fine or flour gold, and costing only 8 to 12*s.* per ton, including mining, which is often only nominal. This process will be described under the head of "Fine gold" (see p. 903). Skidmore states that this machine "for saving gold from the ocean sands has never amounted to anything that I know of." He declares that the variable character of the sands prevents such an enterprise being carried on successfully for any length of time.

In New Zealand a considerable amount of "beach-combing" is carried on where water is available, and with most satisfactory results. At North Beach, a head race was carried 5 miles from the Maori river, costing 600*l.*, and the washing yielded 1 oz. a day per man. At Seventeen-mile Beach, near Greymouth, are over 10 miles of auriferous seashore, with at least 4 lines of pay-dirt, and extensive operations are now being carried on. About 2 miles N. of Charleston is a settlement of Shetlanders, whose working time is divided between small farm cultivation and the working of fine gold from the sea-sands, which, after heavy weather, are easily got at and found to be highly auriferous. These beach-claims are deemed valuable property, and are kept carefully registered. Two double-area claims, each having 200 ft. frontage, with all working appliances, and a large water-race heading from the Little Totara river, fetched 1000*l.* in February, 1882. The claims alone are commonly sold for 200 to 300*l.* each, independently of water-race and appliances.

The following account of beach-mining, as here conducted, has been very obligingly contributed by Warden Revell, in response to a special application on the subject.

Fig. 50 gives a sketch of a "beach-box," which is a fair representative of those now in use. The frame *a* is built entirely of timber, and from end to end measures 14 ft. The hind legs are 2 ft. high, and at the lower end the floor is 18 in. from the ground. The fall is regulated by raising the legs or wheels as may be necessary. The "hose" *b* is 3 in. in diameter, made of stout canvas—generally tarred to preserve it and render it watertight—through which the water is brought and conveyed up the "leader" *c*, thence emptying into the hopper *d*. The bottom of the hopper is a sheet of perforated iron, 2 ft. sq.—the size of the hopper. The perforations are ¼ in. in diameter, and generally about 1 in. apart. The sand is shovelled into the hopper, and the finer part of it is carried through the perforations by the water, and drops upon the "slide" *e* (shown on the sketch by dotted lines), within the box below the hopper. A copper plate is laid over this slide, coated with mercury, to which the gold attaches itself. This slide is 2 ft. wide and 3 ft. long; at its lower end an opening is left 2 in. from the plate beneath it, and the same space from the end of the box, so that the water may drop on the next plate *f*, and from that over plates *g* and *h*, which are also overlaid with mercury. At the bottom of plates *f g h*, "riffles" *i k l* are placed; *i* and *k* are formed by leaving a space between the plates, so as to form a hollow into which the water must drop before reaching the next plate. Above these two riffles, slides are placed to break the impetus of the water when it reaches them, and force it more gently under them. The last riffle-box is of different construction from those above. It is 5 in. in depth at the upper side, 13 in. on the lower, and 5 in. wide. In the centre a slide is placed, and pushed down to within 2½ or 3 in. of the bottom of the riffle-box. The sand and water drop into this box, and are forced out again at the lower side of the "slides," thence running over the last table or "tail-board" *m*. The object of the two first riffles is to break the force of the water, and that of the riffle-box is to catch any loose mercury that may come off the plates above it, and which, on account of its weight, cannot be forced out again by the water. On the "tail-board," instead of mercury, "baize" or blanket is placed, to catch all "rusty" gold that the mercury will not take. On the lower side of each riffle, a "flange" is nailed so as to overlap the plate below and thus prevent the water passing beneath. The plates are secured to the frame by battens, and are nailed at top and bottom. Each plate usually weighs about 14 lb.

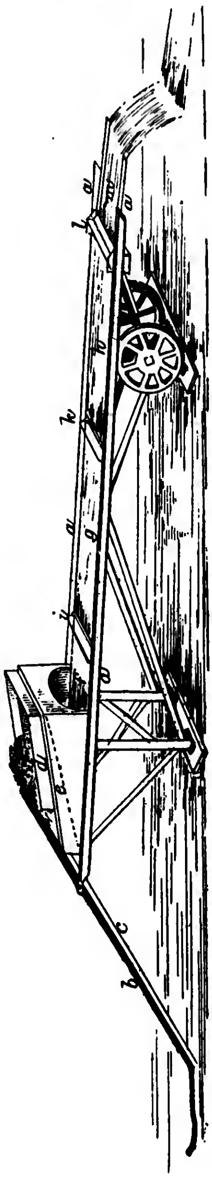


FIG. 50. NEW ZEALAND BEACH-BOX.

When sufficiently rich, the plates are taken from the frame and set on end, so that the loose mercury may run off. They are then scraped with a chisel, both gold and amalgam being taken off. After all the mercury possible has been squeezed from the amalgam, the latter is retorted in the usual manner to free the gold of the mercury entirely. Should any of the copper have been scraped off with the mercury, it will remain with the gold, which latter has then to undergo the process of refining at the banks.

The working results of these claims are various, and almost impossible to estimate, the beaches being often unworkable for months, for it is only heavy seas and strong winds that bring payable gold upon them. Revell thinks, however, that the average wages throughout the year would not be less than 2*l.* 10*s.* per week.

When, by reason of long duration of calm weather, the claims are rendered unworkable, the holders may obtain "protection" from the

FIG. 51.

SHETLANDERS WORKING BEACH-DIGGINGS IN NEW ZEALAND.

Warden for any period not exceeding 6 months. Many avail themselves of this privilege to cultivate the ground round about their cottages —their "Miner's Right" entitling them to hold 24 × 48 ft. without registration, or to the extent of an acre upon registration being granted them by the Warden. Fig. 51 shows a party of Shetlanders working the black sands on the Nine-mile beach, Charleston.

Many of the "beach-combers" are of opinion that the gold on their claims comes from the depths of the sea during the storms, and not from the inland workings, as many others suppose. It is, however, a difficult question to determine.

Flume for transporting timber.—As a considerable quantity of timber is consumed in the construction of box-sluices and most other mining or washing implements and machinery, and the difficulty and cost of conveying the timber to the spot where it is required are often considerable, no apology is needed for inserting here a description of a flume used for carrying timber to the Virginia and Truckie railroad, in Nevada, which might often be adopted with advantage.

It consists of a V-shaped launder or trough, made of 2-in. plank, 18 to 20 in. wide, supported by a light trestle-work, in which a rapidly flowing stream of water carries down cordwood or timber, of such lengths as the curves of the flume will allow passage to, from the head of the cañon to its mouth. In a flume of this description, light timber or plank 10 ft. in length is easily floated and transported. The average grade of the flume is 5° to 6° ; the minimum employed is 1 : 64, though that is rather too slight ; 1 : 33 or 3 ft. in 100 ft. is a very good grade with a fair volume of water. The flume referred to is 5 miles long : cordwood is said to make the entire journey in 18 minutes, and 51 cords of wood have been transported from the upper end of the flume to the place of delivery in 6 hours. At the end of the flume is an iron grating, having the reverse shape of the trough, and inclining upwards from the bottom to the upper edge of the flume. The water passes through this grating, while the wood shoots up on it and falls over the edge of the flume to the ground, where it is piled up or loaded upon the car. This simple method of handling wood cheapens its delivery very much. No men are required, except those who supply the wood to the flume at the upper end, and those who receive and stock it at the lower end. Along the course of the flume, feeding streams are brought in from side cañons at intervals of 1 to 2 miles, to increase the supply of water, and compensate for the wastage occasioned by leaks or over-running. In some of the steeper side cañons, it is possible to use "dry shoots" or similar flumes without water feeding the main flume, the inclination in their case being sufficient to enable the material to slide by the force of gravity alone. By this means, wood is easily delivered from points where roads are impracticable.

Cost of alluvial mining.—The following notes of the cost of alluvial mining in a variety of instances cannot fail to be interesting, as they afford the means of comparison for new undertakings.

At Ballarat the average cost of raising and puddling wash-dirt and getting out the gold in several mining properties is 7*s.* 3*d.* per ton, and the cost of puddling and sluicing in two instances is 1*s.* 7½*d.* per ton.

At Clunes, the average cost in one alluvial mine is 10¾*d.* per ton for puddling, and the average cost of sluicing is 3½*d.* per ton.

At Sandhurst, the average cost of raising "cement" is 3*s.* 6*d.* per ton ; the average cost of carting, crushing, and extracting the gold is 8*s.* per ton ; and the average cost of puddling or sluicing is 3*s.* per ton, including cartage.

At Maryborough, the average cost in three instances of raising cement is 21*s.* 8*d.* per ton ; puddling, 2*s.* 6*d.* per ton.

At Castlemaine, the average cost, in one claim, of breaking cement is 21*s.* per ton ; raising it to the surface and delivering it at the machine, 4*s.* 9*d.* per ton ; crushing the cement and extracting the gold, 3*s.* 9*d.* per ton. The average cost of puddling by one party of miners is 1*s.* 2*d.* per ton.

At Maldon, the average cost, in one mine, of raising cement and delivering it at the machine, is 1*s.* 6½*d.* per ton ; and the cost of crushing and extracting the gold is 2*s.* per ton. At the Forty-foot lead, the average cost of raising, carting, and puddling is 6*s.* 6*d.* per ton.

At Hurdle Flat, Ovens district, ground 16 ft. 6 in. deep, sluice in rock, 4 gr. of gold (or 6*d.* per load) pays well ; 4 men get down and wash 1 ton of dirt every 5 minutes.

These figures all refer to Victoria, and are mostly taken from Brough Smyth.

Cement : its occurrence, treatment, and yield.—On nearly all alluvial gold-fields, whether shallow placers or deep leads, is found a stratum of ferruginous conglomerate, composed principally of rounded and angular fragments of quartz of all sizes, cemented (hence the name) together by the oxide of iron with which the mass is impregnated, and often so hard as to resist everything but blasting. It overlies the bed-rock, in some places resting on it, in others several in. or even ft. above it. In thickness it fluctuates considerably, from 6 in. to 8 ft. or more. Its character varies but little. On the fields near the site of the present town of Maryborough, in Victoria, the depth of the cement was 10 to 13 ft., and it occupied the miners 2 to 3 weeks to get through it by the use of gads. The bottom was a soft, white pipe-clay, and though the wash-dirt taken out at that time was only 6 to 9 in. deep, the nuggets which could be picked out paid the men well. On another part of the same field, the depth was 16 to 24 ft., and the 4 to 6 in. of pay-dirt taken out was full of nuggets. A rush set in, and within 3 months from the date when the first prospector's tent was pitched on the site of Maryborough, at least 30,000 miners occupied the ground. At first, the cement was washed in a long-tom, which was, of course, quite unfitted for extracting the gold, and very much therefore was lost in the tailings. In some instances, a quantity of débris is found overlying the cement, and pays well for washing, as, though not so rich as the solid mass, it is more easily worked. When the miners realized the fact that the gold was imbedded in the cement in such a manner that mere washing would not dislodge it, they began to put it through the quartz-mills, with greatly improved results, and an immense amount of gold was got out of the tailings that had previously been cast aside. Where crushing-machinery was not at hand, the cement was often thrown out of the way, and huge heaps of it might be found about some of the older gold-fields.

Stamping.—The class of machinery first used for reducing cement was the ordinary stamp-battery employed in quartz-crushing; but an improved modification was adopted at some mills, viz. the holes in the screens were made ½ in. instead of ⅛ in. as usual, thus increasing the crushing capacity 25 per cent. without affecting the product of the cement. Warden Carew reports from the Tuapeka district of New Zealand that quartz-stamps provided with a screen made of a kind of wire netting, with ⅛-in. meshes, as a substitute for the ordinary quartz screen of 120 holes to the in., are working very successfully on cement.

For a long time no other plan was tried, as this succeeded in liberating all the gold. Latterly, however, various devices have been proposed as cheaper substitutes for stamping.

A company owning many acres of rich cement, said to be 40 ft. thick, in Nevada, have brought a tunnel 2000 ft. long and 10 ft. wide with the intention of putting down two flumes throughout the entire length of the tunnel, and extending them as far beyond the mouth as may be desirable, there being plenty of fall for "dumps" (i. e. perpendicular drops of considerable height, where the concussion of the fall serves to break up the agglutinated masses) and under-currents. They calculate that by this means the cement, which has hitherto been crushed in stamp-mills, will be completely disintegrated, and the gold set free.

At Amelia, in Eastern Oregon, are cement beds of a known length of 10 or 12 miles, and varying in thickness from 10 in. to 10 ft. and upwards. They lie near the surface, and every rivulet cutting through them has yielded pay-dirt, and in some cases much riches. The bed-rock immediately beneath the cement has often yielded 4*s.* to 1*l.* per pan. A short wet season induced the owners to try a novel method of treatment. During the winter, the cement was excavated and thrown up in heaps, where it slaked and disintegrated under the influence of alternate frost and thaw, and in the spring it was run through sluices, and gave very profitable results. Raymond expresses himself as "not certain that this method will not prove, after all, the best; though with a continuous supply of water throughout the larger portion of the year, it may not be necessary to confine the period of extraction to the winter, nor the period of working to a few weeks in the spring. Probably the disintegration of the cement could be effected at any season by allowing it to lie a certain time, and occasionally wetting it down."

Drake's cement-mill.—A new mill for reducing cement, known as

Drake's cement-mill, has been made by Prescott, Scott & Co., Union Iron Works, San Francisco, for the New York and Calaveras Gold Co. It is in the form of a tube, 40 ft. long, the staves of which are 5-in. T-rail bars. At the upper end of this tubular cage, the cement as broken from the mine is "dumped," or allowed to fall a considerable height from iron cars. When the machine is in motion, the gravitation of the cement drives it against the sharp edges of the T-bars, by which it is disintegrated. At the same time, a large body of water is allowed to enter the upper part of the tube. This helps the work of separation, and carries the finer material and gold between the bars to an apron beneath, which conveys it into the amalgamating-sluices. The boulders and coarse material slide gradually down the machine, over the central and lower riffles, and out to the waste-heap. The machine weighs about 55 tons as it stands, and will be driven by a 50-H.P. engine, with a 14-in. × 24-in. cylinder, and supplied with steam from a boiler 16 ft. long and 50 in. diameter.

Cox's pan.—Another apparatus, for reducing cement by grinding and friction instead of by crushing, is known as the Cox pan. The boulders, which rarely contain gold, are crushed under the stamps with great waste of time and power. This pan was invented to avoid the necessity for that step. It is about 5 ft. in diameter and 2 ft. high, and is intended to hold a charge of about ½ ton. The rim is made of boiler-plate and the bottom of perforated cast iron, through which the finer sand and auriferous materials fall into the sluice-boxes, or other gold-saving appliances provided for their reception. The boulders and large pebbles are discharged at intervals through a section of the bottom of the pan, which is opened like a trap-door by means of a lever, when they have accumulated to such an extent as to retard the operations. Four revolving arms are attached to a shaft, which passes perpendicularly through the centre of the pan. On these arms are fastened steel teeth, something like plough-shares in appearance, which, in the rapid revolution of the arms, break up the cement. An abundant supply of water is distributed while the pan is in motion, and materially aids in the disintegration.

At Table Mountain, in California, a company are using this pan for cement. The gravel is fed in continuously from a hopper, the feeding being interrupted only long enough to discharge the boulders. The dirt released by the action of the pan passes through the apertures in the bottom, whence it runs through 300 ft. of sluice-boxes. The proprietors speak highly of the pan after 2 years' constant use. At a neighbouring digging, two Cox pans are used, worked by 50 in. of water in an over-shot wheel 30 ft. in diameter. Each pan will treat 40 cart-loads = 40 tons per day. It is fed in continuously, about 10 in. of gravel being kept constantly in the bottom of the pan, which is charged with a little mercury, while 100 to 200 ft. of sluice are used below the pan. D. M. Hughes, the manager at this mine, has used the pan for several years, and effected some improvements in it, especially in distributing the water through the pulp while in motion. He says it will work any cement soft enough to yield to the pick, and work it better than any other process; but he admits the loss of a considerable percentage of the fine gold—which, it may be remarked, is not necessarily attributable to the pan.

Raymond gives some further particulars, furnished by another miner at Dutch Flat, where the cement is that known as "blue," and considered as hard as any in the State. The cement is dumped or tipped into a hopper with an inclined bottom, whence it is loaded into the pan by a gate worked by the man in charge of the pan, thus requiring only one handling, which is a great saving of cost. About 1000 to 1200 lb. are usually put into the pan at once, while it is in motion. In the top of the rim of the pan is constantly a stream of 4 to 5 in. of water, which carries the pulverized cement down through the small openings of the bottom of the pan into the sluices, &c., below. The pan is set in motion, and the gate of the hopper is raised to gradually let the charge of cement enter the pan, generally completed in about 2 minutes. It is run about 4 minutes longer, then stopped to open the trap-door, and then again set in motion, so that all the boulders and stones are driven out and fall into a rock-sluice, the fine auriferous matters having already passed through the bottom of the pan. The operation is then repeated as before. Softer material requires less time. The pan will readily work 100 to 125 tons (of 20 cub. ft. to the ton) per 24 hours, and at a cost, including water-power, labour, &c., of about 5*d.* per ton. The hardest cement requires the pan to be worked at 65 revolutions per minute, consuming 8 H.P. This particular one is run by a "hurdy-gurdy" wheel, 10 ft. in diameter. Those previously mentioned are driven by similar wheels; but as the cement is not so hard in their case, the cost is $3\frac{1}{2}$*d.* to $4\frac{1}{2}$*d.* per ton. It is said to do its work very thoroughly and cheaply, every stone being perfectly cleaned, and the cement so pulverized that it is difficult to find the colour of gold in the tailings. The inventor claims that one pan will do the work of a 25-stamp mill. Its cost is small compared with that of the latter, being about 240*l.* The wear and tear is estimated at 5*d.* per day. The cement can be worked for about $\frac{1}{10}$ the expense entailed by stamping, which costs 4*s.* to 7*s.* per ton, and is not so efficient.

Prof. Skidmore says that the Cox pan works well under certain conditions, but those conditions are rarely found. It is now nearly obsolete; the only two known to be in use have been erected at the Derbec mine, near North Bloomfield, Nevada co., of which mine, the inventor of the pan, J. B. Cox, is superintendent.

Cement yields.—The yields obtained from cement are of course various, as in all classes of mining. At one place, 4 men crushed 4 loads of cement and got 184 oz. of gold, and another party 63 oz. from 15 loads. The wash-dirt with which the cement was intermixed was highly auriferous, and gold was found throughout from the surface to the cement encrusted on the bottom-rock. Other Victoria diggings have given:—5 dwt.; over 14 dwt.; 6 dwt. to ½ oz.; 12 oz.; 1 to 2 oz.; 5 to 8 dwt.; 4 oz.; 6 oz.; 7 oz.; 8 oz.; and 2 to 8 oz.—per ton; 5 tons gave 3 oz. 5 dwt.; 20 tons gave 360 oz.; 2 oz. per load were sometimes obtained; also 5 dwt. per load, much being lost; ½ to 1 oz. per load, much being lost; and 4 dwt. per ton, when 130 lb. of tailings gave 17 gr. One of the wardens on the Otago gold-field, New Zealand, states that in the Tuapeka district "a single pennyweight of gold to a cubic yard of conglomerate (cement) will leave a handsome margin of profit."

Saving fine, flour-, and float-gold.—In adopting measures for saving very fine gold, it is necessary not only to remember that the specific gravity of a grain determines its tendency to subside, but also its size, shape, and affinity for other bodies must be taken into consideration. Iron is specifically far heavier than quartz, yet fine iron-filings will float on water while the finest quartz-sand will sink. Gold has a still greater specific gravity than iron, yet if fine gold and fine quartz-sand be placed in water, many particles of the former will be seen floating while the sand sinks at once. Observers have remarked that all metals seem to have a tendency to float on water when in a very fine state, though not always in the same degree. One way of accounting for this phenomenon is by supposing that minute globules of air or vapour attach themselves to the grain of metal, and thus overcome the force of gravitation. It is even asserted that this property or affinity is most strongly developed in the precious metals, while in compounds it is altogether wanting. Experiments have shown that fine particles of gold would remain afloat in water of ordinary temperature for over 24 hours, but that when the temperature was raised to boiling-point or nearly so, the suspended particles of metal sank. One train of reasoning deduced from this is that the heat causes the bubbles of vapour to expand and escape. Another theorist denies that the "film of air which may adhere to the surface of a particle of metal has very much to do with its buoyancy in water," and prefers to seek an explanation on the ground that the "metals when in small particles, are more or less in the state of *laminæ*," this shape preventing them from overcoming the cohesion of the atoms of the fluid. Thus they remain suspended until some disturbance of the liquid turns them edgewise, when they sink, till accident or cause turns them flat again. The effect produced by heating the water is also ascribed to the expansion of the atoms lessening their cohesion, and therefore more readily yielding to the grains of metal; the commotion also would constantly change the position of the grains.

Water.—Brough Smyth gives a practical illustration of the well-established fact that brackish or salt water, such as is frequently pumped out of mines, is quite unfitted for gold-washing. He remarks of the Chinese washing at Sandhurst, in Victoria, that "in ordinary cases, the waters of the creek enable them to pursue their labours profitably; but where even *clear* water pumped out of the mines is diverted into the creek, they are obliged to seek for supplies elsewhere. With rain-water, they can recover very fine gold; but with brackish water, they get from a fourth to a third less." Smyth is disposed to think that the increased specific gravity of the water may partly account for this, that of the "water got out of the claims at Sandhurst" being "certainly not much below that of sea-water," and "Dr. Schweitzer's examinations of the water of the British Channel, show that the specific gravity is 1·0274 at 60° F."

Copper plates.—On p. 865 have been given some details of the amalgamated copper plates specially devised to save the fine gold. These same plates, which have been the subject of much praise in America, were tried in Australia, and proved—by assays of the tailings—to be far inferior to the blankets commonly in use. Under the subject of Beach-combing (p. 892) are some remarks as to the inefficiency of the plates employed in that branch of gold-mining in California, yet with some modifications these plates are still in vogue. Grease or resin in the water greatly interferes with the process; so also does a low temperature. It is said that a solution of cyanide or prussiate of potash is much better than nitric acid for use in applying the mercury to the plates, as there is then no trouble with the green spots of nitrate of copper. Küstel gives another mode of amalgamating the copper plates. He says "a good result is obtained by putting the copper plates into a wooden vessel with sufficient water to cover the uppermost plate 2 or 3 in. Very little sulphuric acid is added to the water—so much as to make it taste like strong vinegar. After 6 to 12 hours, the plates are taken out, washed in the same liquid, and the mercury rubbed over the surface before the plate becomes dry. Washed in cold water, the copper plate is then prepared for use."

McDougall's plan.—McDougall, some years since, patented in America a machine for saving fine gold, which was employed for several months at least in extracting gold from the waste-water of the Eureka and Idaho mines. It consists of 6 troughs, each 12 ft. × 2½ ft., inclined at a slight angle, and having the bottoms covered with copper plates amalgamated and thickly studded with square iron pegs, about 4 in. high and ½ in. square. Over these pegs, close-fitting copper caps, whose outer surface is amalgamated, are placed in such a manner that their corners are presented to the stream. The waste-water, from which has been extracted all the gold that blankets, copper plates, rubbers, pans, riffles, buddles, &c., were capable of getting, is brought into McDougall's works, and runs through the troughs just described. Striking against the pegs, of which the 6 troughs contain 5000, the water surges and eddies about, so that every atom comes into contact with the amalgamated surfaces. The precipitation of the gold is said to be greatly increased by the "electrical action induced by the differences in latent heat between the different metals, copper, iron, and quicksilver. Amalgam forms rapidly, and 2 men are kept constantly employed in cleaning the copper caps and plates. Owing to the almost microscopical fineness of the gold-particles thus saved, the amalgam obtained does not contain as much gold to the ounce as that ordinarily obtained at the quartz-mills. This is, of course, to be expected. McDougall can tell almost instantly what grade of ore is being worked at the mills above him. When they are running what they call "poor" rock, his contrivance saves the most gold; when they are crushing rich rock, he does not do as well. The explanation is, that the rock which they call poor may contain as much gold as the rich rock, but it exists in such very fine particles that their mill process cannot arrest it. It is these fine particles that he saves. In their rich rock, their gold being coarse, they save a greater proportion of it." (Raymond.)

Professors Raymond and Skidmore write at a subsequent date that McDougall's machine realized a good living for the owner for about 2 years. When the rock of the Eureka got poor, McDougall sold his invention to the company for $700. It paid the company well for a few months, but was discarded when the ores ran to low grade. It may be considered a success when the ore is rich and the loss great. The invention is practically defunct.

Sublett's plan.—The process alluded to on p. 893, under the head "Beach-combing," is as follows. The sand is first screened in order to reduce its bulk, and is then subjected for about 24 hours to a solution of caustic potash and common salt. This is to remove any oxide or film that may be upon the gold, and to destroy sulphur and other base substances which would spoil the mercury. The mass is then placed in a pan, and constantly stirred while being heated by a jet of steam for a few minutes. The mercury is then added, and the steam and agitation again applied for 15 to 30 minutes, when the gold becomes thoroughly amalgamated, and the mass, or "pulp," as it is called, is discharged into a vat to cool before putting it through the separating-sluice. The heat expands or partially evaporates the mercury, and, assisted by the agitation, distributes it through the mass in minute globules, where it meets and amalgamates with the equally fine and widely disseminated grains of gold. Too great a heat must be avoided, as liable to flour the mercury more than is necessary, and thus increase the difficulty of re-collecting it. Considering that the amount of heat required to raise the temperature of 1 lb. of water from 32° to 212° F. will raise that of about 30 lb. of mercury through the same range, the reason for this caution is obvious. Great care must be taken to purify the mercury each time it is used, as success depends much upon this. Retorting alone is not always sufficient, as some of the base metals volatilize and pass over with the mercury. The most difficult part of the process is that of separating the fine particles of amalgam and mercury from the heavy black sand, for the plan adopted with quartz-"pulp" is not available for the heavier black sand. The valuable particles will not be precipitated by any concentrating motion, on account of their lightness and minuteness as compared with the magnetic oxide. The difficulty is said to be overcome, and the separation effected without material loss, by means of a system of galvanized copper rollers, grooved spirally, and placed side by side and in layers one above another, so as to break joints and not quite touch, and extending across the sluice, which is 3 ft. or more wide. A screen is placed over the rollers, to distribute the sand and water as they fall, and a galvanized copper plate is put beneath, to catch the mercury as it drips from the rollers. Two or three tiers of these rollers are thus arranged at two or more places, a few ft. apart in the sluice, and drop-riffles or wells are sunk across the bottom, a little below the copper plates, to receive and retain the mercury as it runs from them. The rollers are 1 ft. long, $1\frac{1}{2}$ in. in diameter, and hollow; 6 or 8 are laid side by side and end to end, extending across the width of the sluice. These and the copper plates are kept in a highly sensitized condition and free from verdigris, and as the pulp passes down, over and between their multiplied surfaces, it necessarily brings the fine particles of mercury into contact with some one of them, to which they will adhere, before passing through the whole of them as arranged in the sluice. As the mercury accumulates upon the rollers, it drops from the under side, and the amalgam is cleaned from them in the same manner as from the plates. These amalgamating rollers and their application both to the cradle and the sluice are the invention of William Sublett, who has applied for a patent for them.

Flycatching.—It has been found at Charleston, New Zealand, that the gold does not all settle in the tail-race, but that on the union of the waters of several tail-races a small percentage, well worth saving, floats away. This is arrested by a method termed "flycatching," which consists of a series of blanket-tables placed across stream, like weirs, so that the waters shall flow over each table in succession. The tables are washed in turn, and the gold is streamed from the sand, and caught up by mercury. Many of these "claims" are very valuable, yielding 4*l.* to 7*l.* a week with little labour. In the Charleston district, flycatching has become quite an industry in itself; the following description and accompanying illustrations are due to the kindness of Warden Revell, of that district.

The tables are constructed entirely of timber. Piles 2 or 3 ft. in length are driven firmly into the bed of the creek, and on these are nailed lengths of stout quartering, covered over with 1-in. boards laid close together, so as to form a smooth table. Pieces of lighter quartering are then placed over the boards from top to bottom, forming divisions about 4 ft. in width. Blanketing or cloth—ordinary corn-sacks opened out are frequently used,—is next spread smoothly along these divisions, and securely fastened down by small strips of wood. The tables vary in length from 7 to 12 ft., and are placed in the creeks at intervals of 60 to 100 ft., extending quite across the stream. The proprietors of these rights realise during rainy weather very good returns, varying from 2*l.* to 6*l.* a week, according to the nature of the workings on the terraces

FIG. 52.

"FLYCATCHING" TABLES.

above, and the number of tables [illegible] in the creek. The tables are costly, and liable to be damaged by floods, and not unfrequently by cattle crossing the creek.

Fig. 52 shows one set of tables as set in the creek, with the water running over. Fig. 53 is a view of the tables in full work. The owner has turned off the water from one compartment prior to lifting the blankets for washing out. Spare cloths are kept to replace those lifted, which, when washed out, are ready to fill the places of those in the next compartment. The men wash out the cloths in a large zinc box at

FIG. 53.

LIFTING THE BLANKETS FROM "FLYCATCHING" TABLES.

the side of the creek. The cloths are generally washed out once a day. The fine tailings pass over several sets of tables in their course down the creek. In the illustrations, there are about 12 sets of tables belonging to one man, and some 5 or 6 proprietors of similar rights occupy positions farther up the stream. The creek is named Darkie's Creek, and empties into the Nile river about 10 chains from where the man is standing in Fig. 53.

Yields of shallow placers.—The following figures will convey some idea of the amounts of gold which have been obtained from various surface-washings in different parts of the world. In Victoria, at Dirty Dick's Gully, the miners worked all the alluvium 6 in. to 6 ft. in depth, and got 10 to 16 oz. per tub of 4 small buckets, while there were pockets containing 100 oz. and more. In Donkey Gully, the yield at the sides was 4 to 6 oz. per tub, in the middle 12 to 20 oz.; within a length of about $\frac{3}{8}$ mile, more than a ton of gold has been taken from this gully.

At Red Hill, the average was 12 oz. per tub, while 600 oz. were found in one pocket, and 30,000*l.* worth was extracted from a single claim. At another pocket, 1800 oz. were discovered. In Golden Gully, 18 to 20 oz. to the tub were common; and 456 oz. were gathered from one hole. On Dinah Flat, 252 oz. were taken from one bucketful of dirt. At some places, pounds' weight of gold were not uncommon; 4068 oz. were taken by one party from a claim measuring 18 ft. by 12 ft., and some of their neighbours did even better. At Hundredweight Hill, as much as 360 oz. were washed out of one tub of surface soil. On workings 8 ft. deep at Forty-foot Hill, a claim 8 ft. sq. usually gave 3600 oz. of gold. Even with that rude implement the puddling-machine, 4 men at Castlemaine got gold at the rate of 100*l.* per week. At Sandhurst, the average amount of gold left in the tailings from puddling-machines was about 2 dwt. per ton. One man got 5000*l.* gold in 9 days. Nuggets of 22 lb., 108 oz., and 99 oz. are recorded. At Ballarat East, a tin-dishful of dirt taken from the surface of a hill gave as much as 168 oz. of gold. These figures are quoted from Brough Smyth, and are absolutely reliable.

In the Westport district of New Zealand, a party of 6 men got 800 oz. in 4 months; another party of 3, 100 oz. in 14 weeks; and a third party of 6, 140 oz. in the same time.

From California, come similar figures. One company took out 20,000*l.* per season for two or three seasons. A panful of bar gravel sometimes contained 20*l.* worth of scale gold. The average yield of the companies working on bars in one district was about 20 oz. a day. Individuals have been known to make 6000*l.* a season. A man with a rocker would make 200*l.* to 300*l.* per season. Many companies at Rose's Bar made 15,000*l.* per season in the rivers. At the mouth of the Rabb Ravine, near Timbuctoo, the yield was 20*l.* a day per man; there were 20 men at Timbuctoo who made an average total of 80*l.* per diem, without any proper facilities. On the Cement Mine Ravine, 2 oz. a day to the man was very common. At Square Creek Ravine, some companies made runs of 18 days, in which 3 or 4 men usually netted 1000*l.* to 1200*l.* At other spots, surfacers made 10*l.* to 20*l.* a day to the hand. One authority estimates the average yield of placers over a large area at a minimum of 2*l.* per diem per man, and thinks 3*l.* more nearly correct. Some individuals made 6000*l.* to 8000*l.*, and then left. These accounts show only the bright side of the picture, and it is scarcely necessary to remark that there have been instances where the cost of working was not even repaid by the gold found.

CHAPTER IV.

DEEP LEADS OR DEAD RIVERS.

Definition.—A "deep lead" is a deposit of auriferous gravel, lying at a considerable depth beneath the surface, and often covered by beds of lava or basalt, hundreds and even thousands of feet thick. This deposit is to be distinguished from a shallow placer or surface washing by the fact that it has been the work of a drainage system which no longer exists. Like the modern placer diggings, deep leads are generally, though not always, fluviatile or riverine.* In California, indeed, they are known as "dead rivers," a term which is applied only to channels which were occupied by running streams in past geological ages, and are now filled up with earthy or rocky matter. They are not to be confounded with channels that are open and remain dry during a part of the year from lack of water, or which have been abandoned by their streams for other channels. A dry river-bed is not a dead river. In almost all instances, these ancient deposits have been discovered by following up a modern auriferous stream, and tracing the wash-dirt onwards into the deeper ground, whence part of it had been dislodged by the recent stream. It is often easy to judge whether the gold in a modern placer or shallow washing has been derived directly from a quartz reef or from a deep lead, as that from the reefs is generally coarse, heavy, and not much water-worn, while that from the leads is usually fine and rounded.

The erosion due to rivers, and, perhaps, also sea-waves, has destroyed the veins, and formed a great deposit of mud and clay in the valleys; while in many cases the gold-bearing veins, the streams which wore them away, and the deposit formed by the streams, have all disappeared, and the gold has to be sought in more recent accumulations, which have undergone a variety of changes and perturbations.

It is scarcely possible to do more than guess at the age of the Tertiary rocks in which the deep leads are found, and the evidence on this head has to be sought rather in the relations borne by these deposits to the adjacent formations than in any fossils which they may yield. Still the limits are often sufficiently well marked to meet practical demands. The deep leads were long supposed to be in no case older than Pliocene;

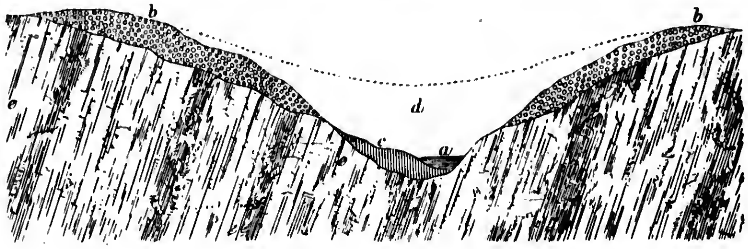
* An exception is to be found in the lacustrine deposits of the Otago gold-field, New Zealand (see pp. 549–50).

no marine relic has apparently been found in auriferous drifts, and no gold-mining is known to be carried on in drifts underlying marine fossiliferous strata. But the greatest distrust must be maintained towards these dogmas; the deep leads and other strata have only been very imperfectly studied, and at any moment gold may be discovered in Secondary or Tertiary fossiliferous rocks. Indeed, since this work has been in preparation, the Fifth Report of Progress of the Geological Survey of Victoria states that extensive and rich gold-washings have been found and partly worked in distinctly fossiliferous Miocene strata, overlaid by a capping of basalt, in some places 700 ft. thick.

Rarely is it possible to trace the course of a deep lead within such limits as will serve the turn of the gold-miner, merely by the indications furnished by the natural surface of the land overlying them. The course of a channel originating in a range of Palæozoic rocks may for some distance be well marked by strata of gravel, sand, and water-worn quartz pebbles filling up the lower part of the valley; but when it is followed out into the low plains, through which the modern stream has cut its way, the strata may, and almost certainly will, increase in thickness, so that it becomes impossible any longer to follow the trend of the ancient river-bed. By noting the direction of the boundary ridges, it may be possible to indicate the limits of the deviations of the channel; but where the distance between them is considerable, which is very generally the case, much money may be fruitlessly spent in sinking in search of the lead. In Victoria, some little guidance may be derived from the fact that it has hitherto been found that almost all the leads run parallel to the modern rivers, whereas in California they are more commonly at right angles to the latter; and even under the best conditions, the sinuosities of the ancient channel cannot be taken into calculation, neither is it possible to foretell where the bed may widen and where it may become narrow, points which, as will be seen presently, have a vital bearing upon the payable character or richness of the auriferous lead. When a lead is overlaid by basalt, the miner's difficulties are increased. In some localities, it is true, the direction can be determined within limits sufficiently restricted for theoretical purposes, because the outcrops of the bed-rocks are visible on either hand, and their elevation above the valley or plain can be fixed. But to the miner, only two courses present themselves: if he will ascertain the course of the lead with accuracy, he must undertake expensive subterranean explorations; approximately, he may succeed by putting down borings. Yet even when the general trend is known, and the width reaches a mile or two, nothing is easier than to miss the richest part of the lead. The undulations of the surface afford no clue, and are often very misleading; and when the lowest depressions of the underlying strata have been found at the expense of boring, it may chance that the richest deposits of the gold do not lie there, but in the "reef-washes" or "benches" at the higher levels. A "reef-wash" is a deposit of wash-dirt spread over an expanse of flat or undulating "reef" or bed-rock, or lodged in a hollow in it above the level of the "gutter" or true bed of the water-course. For instance, towards the junction of two leads, the wall of reef or bed-rock by which the two leads are separated appears in some cases to be worn or broken down, and a stretch of comparatively flat rock is left between them: if covered by a layer of wash-dirt, and raised above the level of the water-courses, this would be called a "reef-wash." Also where the rock on one side of the water-course spreads out at a higher level, and a channel containing wash-dirt is found running alongside the true gutter, and between the gutter and the wall of the bed-rock, it is called "reef-wash." Several instances have occurred in Victoria where considerable alluvial gold deposits have been found and worked at distances of 200 and 300 yd. from the gutter, which had already been exhausted and deserted. Sometimes the outcrops of deep leads may be discovered by prospecting along the edges of the basalts. It seems to be considered as an established fact that there are no auriferous quartz veins in the mesozoic strata of Victoria, and therefore it may be assumed that any gold found resting upon them must have been conveyed from older rocks containing auriferous matrices; this is considered to preclude the probability of any rich deposit of gold being found on them.

Formation.—Auriferous leads seem, so far as is known, to present closely similar features wherever they may be found, whether exposed, or covered by basalt or recent sedimentary deposits. It must be remembered that even the hardest rocks are worn away by the combined action of air, rain, wind, sun, dew, and frost, and are rendered capable of transport by streams. These latter act in two ways: they cut into the rocks through which they flow, and at the same time they deposit in their courses the heavier particles of material brought down from the neighbouring elevations. In this way, alluvions are formed. If the stream is powerful, the fall not very great, and the rocks soft, a comparatively wide deposit of drifts and clays will be arranged, according to the specific gravity of the materials, modified, however, by the size and shape of the particles; and these strata will gradually increase in thickness till the lower part of the stream begins to acquire greater force from the steeper fall there produced, and scoops out a deeper channel for itself. In time, it will wear back towards the source, and a new and deeper course will be cut through the alluvions and bed-rock. The action is illustrated in Fig. 54. The stream *a* represents the "gutter" of a lead; the drifts *b*, the "reef-wash"; *c*, newer drift; *d*, older drift cut through and carried away; *e*, bed-rock. It is often supposed that the reef-wash must necessarily be younger than the drift in the gutter, but it is quite possible that it may even be older in some instances. Evidently many successive layers of different ages may be formed in the same way, and where it can be proved that the stream has always

FIG. 54.



SECTION SHOWING "REEF-WASH."

been cutting a deeper channel, it may be assumed with certainty that the upper drifts or reef-washes are older than those lying deeper down. A stream will seldom continue to make a deposit in the direction of its course for a lengthened period and until its channel is changed; but this does occasionally happen where the bounding ridges are low. In such a case, the bed will gradually be silted up, and it will be almost impossible to ascertain the relative ages of the deposits, especially when the lithological features remain the same throughout.

The rate at which alterations are effected by streams of water depends in a great measure upon the nature of the rocks exposed to their action. When the strata are inclined, and composed of soft sandstones and argillaceous rocks, materials will be transported and new channels excavated in a manner which is not known when the rocks are hard or lie almost horizontally. The stream *a*, shown in Fig. 55, would rapidly erode the rock against which it impinges, and would be assisted by every shower of rain, the upper portions falling down as fast as the lower parts were worn away. The bed would constantly move towards the right, and the earthy materials of all kinds would be disintegrated and transported to form a new deposit in some portion of the bed of the stream.

In Fig. 56 may be observed the effects of another co-operation of forces. The stream *a*, wearing away the rocks on the right, would cause masses to fall from time to time, and landslips would also take place. Surface water percolating through the layers of clay at *c* would facilitate this, and an insignificant rivulet would soon materially change its bed. When claystones form a part of the strata in such cases, the layers will not hold together, and large masses will slide down at a time.

This kind of erosion often gives rise to important changes, of which a common example is shown in Fig. 57. Sometimes, by examining an ordinary horseshoe bend, it will be seen that the stream has at various times overflowed and denuded nearly every part of the surface of the peninsula *c*, which thus becomes much lower than the adjacent country. The stream having finally cut its bed, as indicated, continues to wear away the sides of the range at *a* and *b*, in the manner represented, until at last the isthmus is cut through, the channel deepened, and, in the course of time, the old bed surrounding the peninsula is almost obliterated.

Fig. 55.

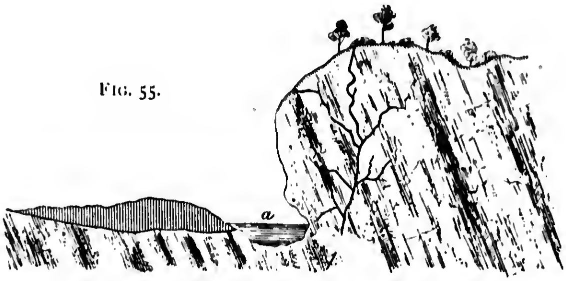
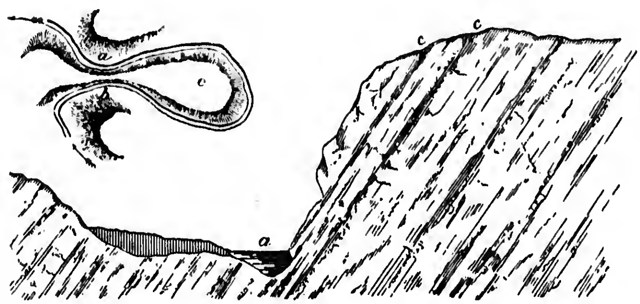


Fig. 57. Fig. 56.



Sections showing Erosive Action of Rivers.

It is commonly remarked of the Victorian rivers which run through basalt and Silurian claystone districts, that their beds are cut along the line of junction of the two formations. This is due to the softness of the argillaceous claystones. Rain falling on the claystone ranges would first settle in the hollows of the line of junction, decomposition and disintegration would follow, and a channel would soon be cut in the softer rocks in the line of the depression.

The diagrams just given are from actual sections by Brough Smyth, but they only represent the simplest changes met with. A deep study of and intimate acquaintance with the geological disturbances which have been developed in a district, must always prove of immense assistance to the seeker after deep leads. It is, in fact, the point which demands the greatest attention, and ought to form the basis for all mining operations undertaken in this class of deposits. The following diagrams, therefore, cannot fail to be found exceedingly interesting and instructive. They are due to Captain Couchman, chief mining surveyor in the Maryborough district.

In that district, the shallowness of the auriferous alluvions on the summits and slopes of the clay-slate ranges and the regularity of their direction are generally remarkable. They afford also evidence of the great changes that have been developed in many of the drainage channels. They are commonly found in or near the present water-courses, but there are many exceptions to this rule, one of the most important of which is illustrated in Fig. 58. Here the old valley beds

FIG. 58.

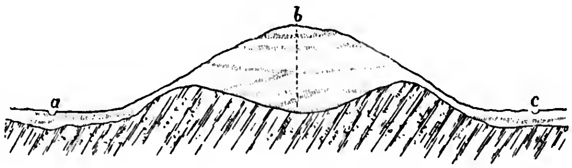
DEEPLY-SILTED GUTTERS FAR FROM PRESENT STREAM.

have been silted up to high levels, forming wide alluvial flats, and the wash-dirt *b c* is found far from the present water-course *a*, though still in the same flat. This feature seems to have originated in a constant shifting of the bed of the stream during the time that the valley was being silted up, as evidenced by the successive layers of clay, shingle, ard sand.

It sometimes happens that after old channels containing auriferous alluvial deposits have been silted up in a great measure, deeper valleys are worn down on either side, so that what was formerly a valley is made to assume the appearance of a hill, as shown in Fig. 59. The hill from which this illustration is taken has the outward appearance of a clay-slate spur, but really consists chiefly of alluvial deposits, in which gold has been found immediately under the summit ; *a c* are modern water-courses, *b* is wash-dirt.

Where flows of basaltic lava have wholly or partially covered the Silurian claystones, &c., the courses of the modern streams often vary widely from the direction of the older valleys beneath, though exhibiting conformity in the general tendency of the main drainage between the watersheds and the sea or the chief rivers.

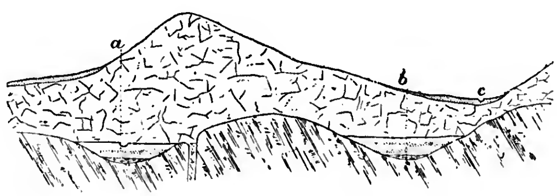
FIG. 59.



GUTTER HIDDEN BY ALLUVIAL HILL.

An instance of complete capping with basalt is shown in Fig. 60. New river channels *c* have cut their way in the basalt in the lines governed by the depressions and slopes on its surface, while beneath, as

FIG. 60.



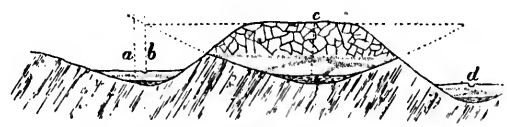
GUTTER COMPLETELY CAPPED BY BASALT.

at *a* and *b*, deep leads of auriferous alluvium occupy the beds of the ancient river system.

Where the basalt is of an indurated description, and its flow has been restricted within the limits of a narrow valley, the formation will assume the character illustrated in Fig. 61. The basalt was confined to the bed of an alluvial valley in the older sedimentary rocks, probably bounded on either side by hills sloping in the direction of the dotted lines, the volcanic rock conforming with the level of the horizontal broken line. The basalt has succumbed to the degrading influences of the elements much less readily than the adjacent claystones, and thus newer valley beds have been eroded at each side to a lower level, and the ancient river channel with its coping of basalt is left standing as a hill or small plateau ; *a c*, wash-dirt ; *b d*, existing water-courses. In all parts of Victoria where the leads have been explored, it has been noticed that the existing main-drainage channels have been determined by the form of the surface of the Palæozoic rocks. Recent lava-flows have modified the valleys, and varied the courses of the streams; but the main features, resulting from the aqueous agencies at work previous to and during the formation of the leads, remain, though difficult to trace.

With regard to the shallow, auriferous hill deposits before spoken of, miners commonly suppose them to be of more recent formation than the

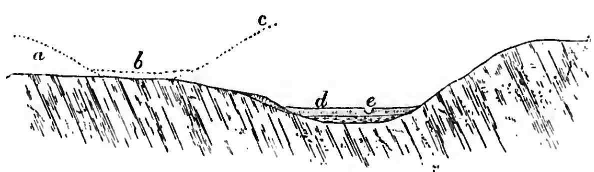
FIG. 61.



GUTTER BENEATH ERODED BASALT HILL.

leads in the valleys, and consider them to result from a later disintegration of richly auriferous quartz veins in the immediate vicinity. This may possibly be a correct view of some of those deposits which do not lie directly on the bed-rock; but where they are in actual contact with the Silurian strata, and the gold and quartz detritus bear a water-worn appearance, attesting a process of friction and disturbance such as the materials forming the valley leads have been subjected to, there is no room for such a theory, and they must rather be taken as special illustrations of the extraordinary changes that have been effected in the river-beds of the older sedimentary rocks by ordinary agencies still at work. The chief causes which have governed the changes that have

FIG. 62.



SECTION SHOWING CHANGE OF RIVER-BED.

taken place in many of the valleys in schistose formations may be briefly stated as the greater disintegration of the argillaceous rocks over the others in the same drainage area; the tendency of rocks to wear chiefly in the direction of the dip of the strata (as illustrated by Fig. 62), owing to the more direct and powerful influence of the elements upon the exposed edges; the more swift erosion of the steepest hills, on account of the rapidity of the drainage and the redoubled scouring action of rain-storms on the slopes; the shifting of water-courses from one valley to another lower, by a channel being cut through the dividing range; and the action of streams from tributary valleys in a lateral direction across the main valleys. In Fig. 62, *a c* are old hills; *b*, an old valley; *d*, a new valley; *e*, existing water-course.

The positions occupied by the gold in the leads are very diversified: in some strata, it is scattered throughout from surface to bed-rock; in others, it is peculiar to the thin layer of quartz pebbles and alluvial drift lying on the bed-rock; in many places, false bottoms occur.

It might be supposed that in the case of a rich stratum of gold being found actually lying upon the bed-rock, the whole of the auriferous deposit had accumulated at one time, and that the barren alluvium was subsequently superimposed. This was, however, by no means the case. It is evident that the flow of water and earthy matters contained from first to last a certain proportion of atoms of gold, whose size was governed by the dimensions of its original matrix, and the degree of abrasion and reduction to which it had been subjected, the latter depending on the force of the motive power, and the obstacles met with. Having stopped in some hollow, the superior weight of the precious atoms would cause them to sink through the moist surrounding matters, till a hard layer was met with. The recurrence of this process would constantly add to the deposit, the gold always gravitating towards the bottom, quickly or slowly, according to circumstances. If water was held long enough to soften the previously deposited material, the bottom would soon be reached; but if the water passed off at once, the gold would remain principally on the surface of the last layer, or partly scattered through the newly deposited mass, and thus the heaviest and smallest particles—their shape being favourable—would continue to descend, so that in course of time the largest proportion must accumulate in the lowest parts, and above strata that are impermeable to water,—generally the bed-rock. Time and circumstances may render it probable that several strata of gold may be found, independent of a considerable amount pervading the whole alluvial deposit, through not having had an opportunity of settling down.

Surprise has often been expressed at the discovery of large water-worn boulders of quartz and other rocks in the alluvions of little channels, where the stream is insignificant even in wet weather, and certainly incapable of moving them under ordinary circumstances. Their abrasion and transportation are generally to be attributed to floods, often occurring where the formations resemble those shown in Figs. 55, 56. Sometimes also the detritus has been derived from drainage areas no longer in connection with the modern stream. When a lead is struck, much uncertainty must surround its relation to other leads, until it has been opened up to some extent. Short of actual exploration, perhaps the safest guides are the character of the detrital matter in the gutter or bed of the lead, and the direction of the fall of the water; but they are not infallible, for the colour, character, and even mode of occurrence of the strata may vary greatly in the same lead, owing to the influence of tributary streams, and water may in a similar manner be introduced in large quantities, and thus give rise to serious errors. It is very necessary to bear in mind that the gutter or actual bed of the stream does not represent by any means the distribution of the auriferous ground; the width of the lead is not confined to the gutter, and sometimes the yield of gold is greater from other parts of the lead than from the gutter itself.

Sections.—Sections of the strata cut through in reaching deep leads are very interesting, both to the miner and the geologist. Those hereafter given are principally on the authority of Brough Smyth, and refer to Victoria:—

	ft.	in.
1. Black soil	4	0
Red gravel	2	0
Red clay	13	0
Drift	34	0
Boulders	3	0
Cement and sand	3	0
Auriferous drift	2	0
	61	0

Bottom: Micaceous sandstone.

	ft.	in.
2. Red clay	7	0
Basalt..	90	0
Boulders	9	0
Auriferous drift	3	0
	109	0

Bottom: Green slate.

	ft.	in.
3. Soil	7	0
Red clay	8	0
Black clay	35	0
Decomposed basalt	10	0
Black clay	11	0
Boulders	15	0
Auriferous drift	8	0
	94	0

Bottom: Schistose.

	ft.	in.
4. Surface soil	2	0
Stiff yellow clay	8	0
Drift (dry)..	13	0
Stiff yellow clay	9	0
Fine sand	2	0
Ditto, darker colour, with a little gravel	4	0
Fine white sand	4	0
Cement of drift granite and sand	14	0
Arenaceous clay	23	0
Fine yellow clay	3	0
Coarse drift	12	0
Fine drift sand and clay	1	0
White and yellow clay	2	0
Fine drift (no water)	4	0
Very tenacious white pipe-clay	3	0
Dark-yellow clay and grit ..	9	0
Very fine running drift (much water)	15	0
Stiff blue and red clay	2	0
Light-coloured drift..	1	0
Stiff blue clay	1	0
Tough black clay mixed with charcoal	5	0
Blue clay	2	0
Very tough clay	4	0
Red clay with streaks of white and yellow	112	0
Cement (false bottom)	2	6
Hard cemented granite drift ..	3	0
Coarse gravel	3	0
Auriferous coarse drift gravel	7	0
	270	6

Bottom: Soft white slate and pipe-clay.

		ft.	in.
5.	Surface soil	2	0
	Sandy clay	18	0
	Brown sandy clay	18	0
	White sand	2	0
	Yellow clay	20	0
	White pipe-clay	2	0
	Red sandy clay	2	0
	Dark-brown sandy clay	14	0
	Water	2	0
	Variegated sandy clay	9	0
	Red sandy clay	2	0
	Yellow clay	10	0
	Yellow sandy clay (more water)	19	0
	Red sandy drift	10	0
	Yellow clay	10	0
	Red clay with streaks of white and yellow	81	0
		221	0

Bottom: Yellow slate rock. No drift, no gravel, and no gold.

		ft.	in.
6.	Surface soil	2	0
	Stiff yellow clay	18	0
	Coarse granite drift, very hard	4	0
	Stiff yellow clay	16	0
	Very fine sand	4	0
	Coarse granite drift with clay and fine sand	14	0
	Stiff variegated clay	2	0
	Hard red granite drift	4	0
	Very stiff variegated clay	3	0
	Hard red granite drift	4	0
	Red and white clay, very hard	4	0
	Stiff yellow clay	9	0
	Hard granite mixed with a little clay	7	0
	Hard red granite drift	1	0
	White clay and fine sand	2	0
	Fine soft yellow clay	2	0
	Granite drift and clay	3	0
	Soft white and yellow clay	2	0
	Granite drift with a little water	9	0
	Red and yellow clay	15	0
	Red, white, and yellow clay	2	0
	Very fine (dry) light-coloured clay	3	0
	Fine dark-coloured drift with charcoal	3	0
	White clay with quartz	3	0
	Red clay with streaks of white and yellow	120	0
	Red sand (cement)	0	6
	Coarse granite drift, very hard, with very little water	2	6
	Auriferous drift, colour of gold obtained	2	0
		261	0

Bottom: Yellow slate rock.

		ft.	in.
7.	Surface soil	2	0
	Clay and sand	38	0
	Drift	14	0
	Clay	27	0
	Drift	6	0
	Clay	11	0
	Clay, sand, and drift	15	0
	Clay mixed with drift	25	0
	Black stiff clay	4	0
	Yellow and blue clay	18	0
	Red clay with streaks of white and yellow	102	0
	Auriferous drift gravel mixed with cement	4	0
		266	0

Bottom: Soft white slate and pipe-clay.

		ft.	in.
8.	Surface soil	1	0
	Red sandy gravel mixed with fine quartz	40	0
	Fine quartz gravel, not water-worn	10	0
	Very fine white indurated clay, with a slight appearance of stratification and verging towards cement at the base	43	0
	Compact sand	3	0
	Quartzose gravel	3 to 5	0
	Auriferous drift resting on Silurian bed-rock	5	0
		107	0

		ft.	in.
9.	Loam and clay	2 ft. to 4	0
	Ferruginous cement	2 ft. to 4	0
	Gravel, sand, and angular fragments of quartz	20 ft. to 30	0
	Fine compact gravel	2	0
	Cement (sometimes wanting)	3 in. to 1	3
	Auriferous drift	5 ft. to 12	0
	Very fine compact indurated clay (false bottom)	20 ft. to 50	0
	Auriferous ferruginous cement lying on clay-slate (true bottom)	6 ft. to 10	0
	Maximum	113	3

Only the lower part of either stratum in No. 9 is very rich in gold. Towards the sides of the gutter, near the bounding ranges, the two bottoms do not seem to be found; but this is not made clear. Invariably the two bottoms are met with wherever a tributary enters the main lead. Probably the two gutters do not follow the same direction, or the lower lead may be wider than the upper.

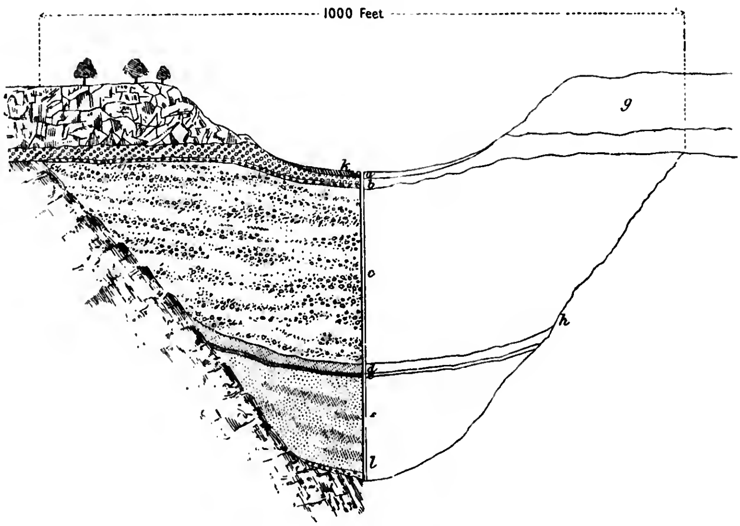
		ft.	in.
10.	Black surface soil	0	9
	Clay with quartz-gravel	10	0
	Basalt	48	0
	Stiff clay	8	0
	Quartz drift	2	0
	Wash-dirt (quartz-gravel) 9 in. to	2	0
		70	9

Fall of the gutter: 3 ft. in every 100 ft. Ferruginous cement sometimes met with.

		ft.	in.
11.	Black surface soil	2	0
	Clay with quartz	7	0
	Basalt	52	0
	Stiff black clay	9	0
	Quartz drift	3	0
	Wash-dirt .. .. .. 8 in to	3	0
		76	0

Width of gutter: 200 ft. and not fully explored. Fall: 3 ft. in every 100 ft. Ground very wet.

Fig. 63.



Miocene Leads at Tea-tree Creek.

Fig. 63 represents a section of the leads at Tea-tree Creek, Moorabool, which are believed to be of Miocene age. All the ordinary gold-workings, as here shown, are carried on in a recent drift, immediately underlying the basalt and overlying the older strata. The gold is fine, but generally distributed, and has been profitably worked for several years. The reference letters indicate as follows:—*a*, black clay and loam; *b*, gravel containing considerable quantities of fine gold; *c*, 320 ft. of cement, quartz boulders, &c.; *d*, 9 ft. of drift; *e*, dark clay with imbedded trees and fine gold; *f*, cement drift with layers interspersed with gold; *g*, basalt; *h*, schist; *i*, reef containing coarse heavy gold; *k*, creek; *l*, shaft 460 ft. deep. The Golden-Rivers Company sank 460 ft. in order to reach the bottom, in the hopes of finding richer ground than the lead on the false bottom which they were working. After passing through a drift containing small well-rounded pieces of quartz and a great deal of pyrites, a seam of black clay was struck, enclosing fossil trees and a little fine gold, and beneath this a thick layer of grey sandy clay with small fragments of fossil wood. On the hard yellow sandstone bed-rock, every sample taken from the lead yielded gold, and the precious metal was found to be present wherever the true bottom was laid bare, but not in sufficient quantity to pay for working.

Another section near here shows:—

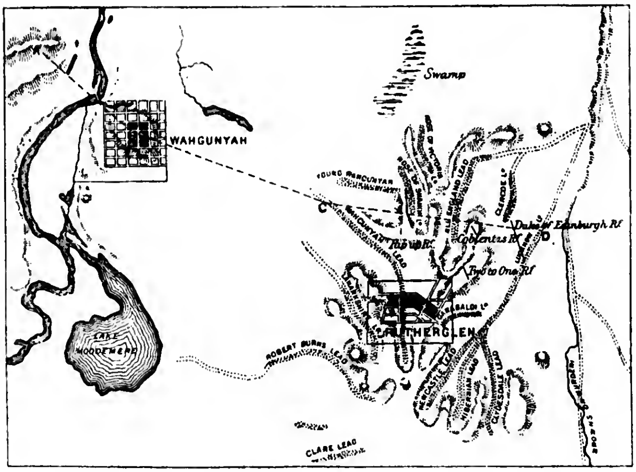
Upper basalt rock, about 25 to 30 ft.
Pliocene gravel, about 50 to 60 ft.
Miocene gravel, &c. (the "false bottom"), gravel, sand, clay and boulders, with fossil leaves and wood, about 400 ft.
Silurian slates, &c.

A third section runs:—

Upper basalt, 49 ft.
Sandy Pliocene grit, 10 to 15 ft.
Upper coralline limestone, 13 ft. } Miocene.
Older basalt containing bands of hard compact limestone with fossils. } Miocene.
Sandy limestones, with fossils, 30 ft. } Miocene.
Rounded quartz pebble drift, and hard silicious conglomerate rock with fossil wood, lower part gravel and boulder drift, 90 ft.
Silurian slate and sandstone with quartz veins.

Figs. 64 and 65 show a plan and section of the leads in the neighbourhood of the Murray river, Victoria, copied from Brough Smyth's work. The horizontal scale is 30 chains to 1 in.; the vertical, 200 ft. to 1 in. The break between the two portions of Fig. 65, representing the area occupied by the probable ancient bed of the Murray river, may be understood to have a width of 150 chains. The letters of indication on Fig. 65 have the following reference:—*a*, red-chocolate coloured soil, with a few rounded and sub-angular quartz pebbles; *b*, the surface of this flat consists of a tenacious marly clay, overlying the ordinary river drifts, probably of no great depth; *c*, banks consist of nearly perpendicular rock about 50 ft. above the present level of the stream, composed of brown, white, and red sandstone and slate-rock; ferruginous quartz ve[illegible] particularly numerous, having every direction from perpendicular to horizontal; *d*, red soil, overlying clay-slate and sandstone rock; *e*, marly clay, used in brick-making; *f*, surface covered with vast quantities of rounded and sub-angular quartz pebbles; gold has been found in the stone; *g*, a drain in this gully shows a considerable quantity of surface limestone nodules; *h*, quartz pebbles: brown and red clay soil; *i*, total depth of shaft said to be 235 ft.; the width of the lead never exceeds 40 ft.; when it runs out in a fine drift 2 ft. 6 in. thick, the wash-dirt is about 5 ft. 6 in. thick; bed-rock of the usual schistose formation; *j*, a quartz-prospecting shaft sunk on this hill shows 3 ft. of alluvium overlying the sandstone and slate rock, intersected by several very narrow quartz veins, running down quite perpendicularly; *k*, quartz pebbles very

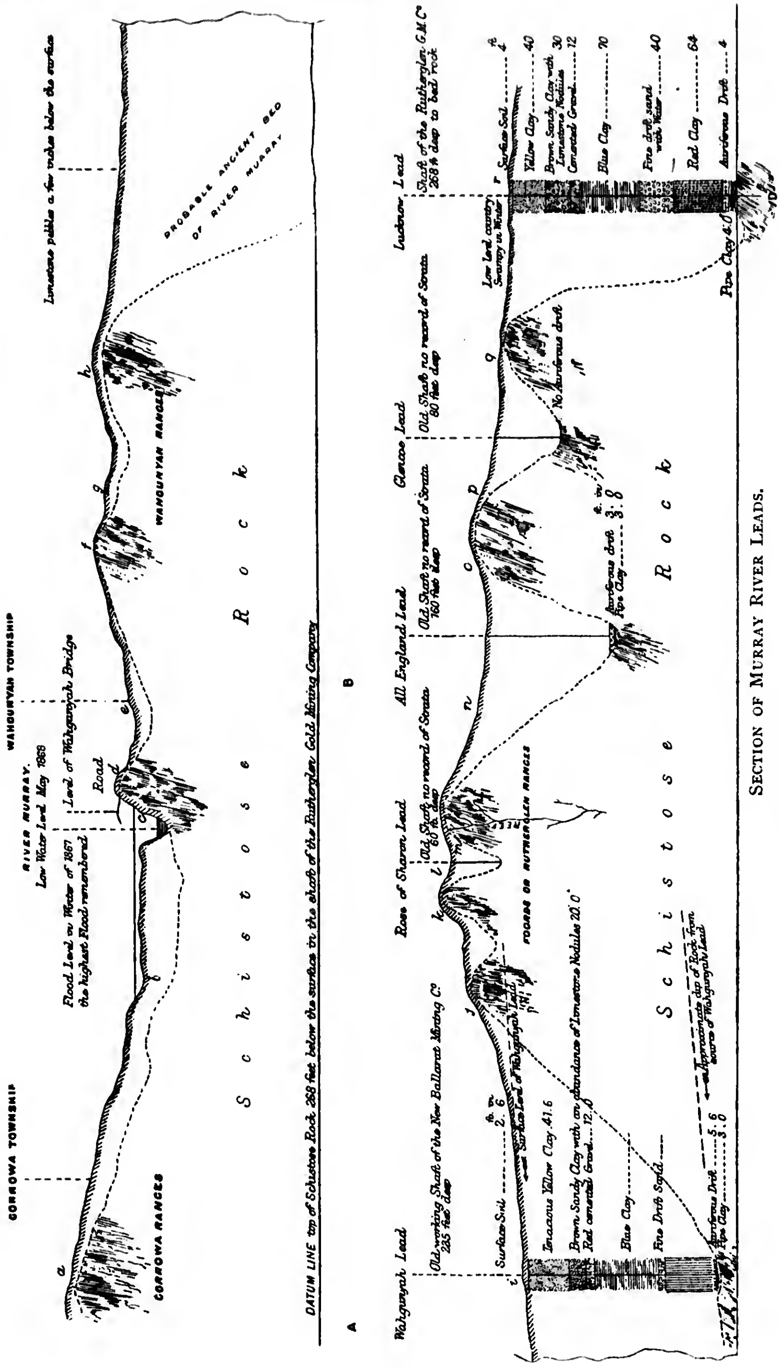
Fig. 64.



Plan of Murray River Leads.

plentiful on this hill; no exposure of rock; *l*, shaft about 60 ft. deep; the lead very poor and unimportant; *m*, the veins are very small, the largest not more than 4 or 5 in. thick; *n*, this has been one of the most productive leads in the district; the depth of the last shaft sunk was 285 ft., the wash-dirt was 2½ to 5½ ft. thick, and the width of the lead was 40 to 80 ft.; *o*, there is no exposure of rock on the sectional line, but on the apex of the hill several quartz veins have been extensively worked; *p*, this lead seems to have originated in the quartz veins intersecting the apex of the low Silurian range; the depth of sinking is 260 ft., with wash-dirt 60 ft. wide and 2 to 5 ft. deep; *q*, close here is a thin deposit of alluvium covering schistose rock intersected by quartz veins;

FIG. 65.



SECTION OF MURRAY RIVER LEADS.

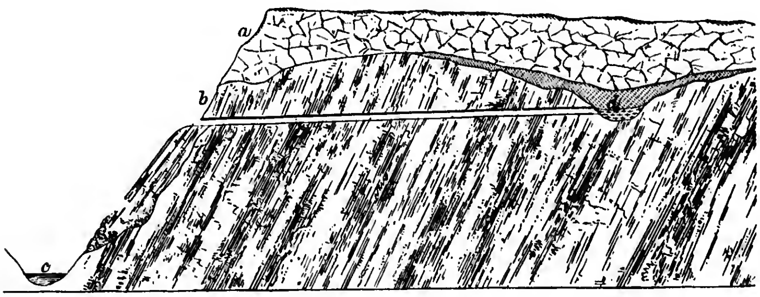
r, a highly payable lead for a distance of 154 ft. west from the shaft; drift chiefly composed of sub-angular fragments of quartz.

In the main lead, at Bendigo, are two layers of cement, one formed on the top of the wash-dirt, 1 to 7 ft. from the bed-rock, where the gold is so fine as to be called "paint-gold," yet so abundantly and thoroughly disseminated through the rock that it averages 5 to 6 dwt. per ton, and sometimes reaches 1½ oz. It is exceedingly hard, and has to be broken down with sledge-hammers, as the loose, sandy character of the overlying stratum precludes the use of gunpowder. The other layer of cement lies on the bed-rock, and is only 1 to 4 in. thick. Some of it is brittle and even friable, and it has been found exceedingly rich in places, seams of it running for 18 in. into the bed-rock, while its average yield has been 1 oz. per ton. The strata are about as follows:—

	ft.	in.
Sandy loam	1	6
Sandy clay	10 ft. to 12	0
Gravel like road-metal	30	0
Sand in layers	30	0
Tough clay	4 ft. to 6	0
Fine drift sand	11	6
Gravel and boulders	3 ft. to 9	0

In the Daylesford district, the lines of the outflows of volcanic matter can be distinctly traced, notwithstanding the changes effected by denudation. The alterations in the contour due to riverine action are partly referable to the great extent of heavily wooded country lying to the south, on and near the Main Spur, where rain falls nearly all the year round. The streams fed from this source have cut deeply into the

FIG. 66.

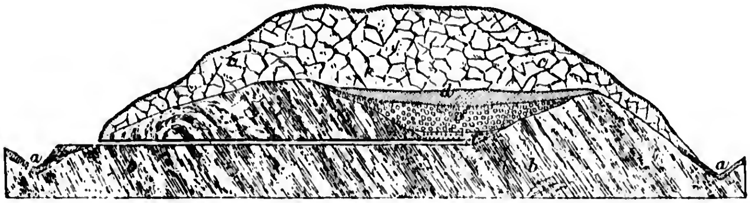


DEEP LEADS IN THE DAYLESFORD DISTRICT.

basalts and Palæozoic clay-stones, and the leads or ancient river-beds have to be sought for in the bounding ranges of the present valleys rather than deep beneath the surface of the latter. The modes of occurrence of most of the deep leads in this district are represented by the actual sections depicted in Figs. 66 and 67. In Fig. 66, *a* is basalt;

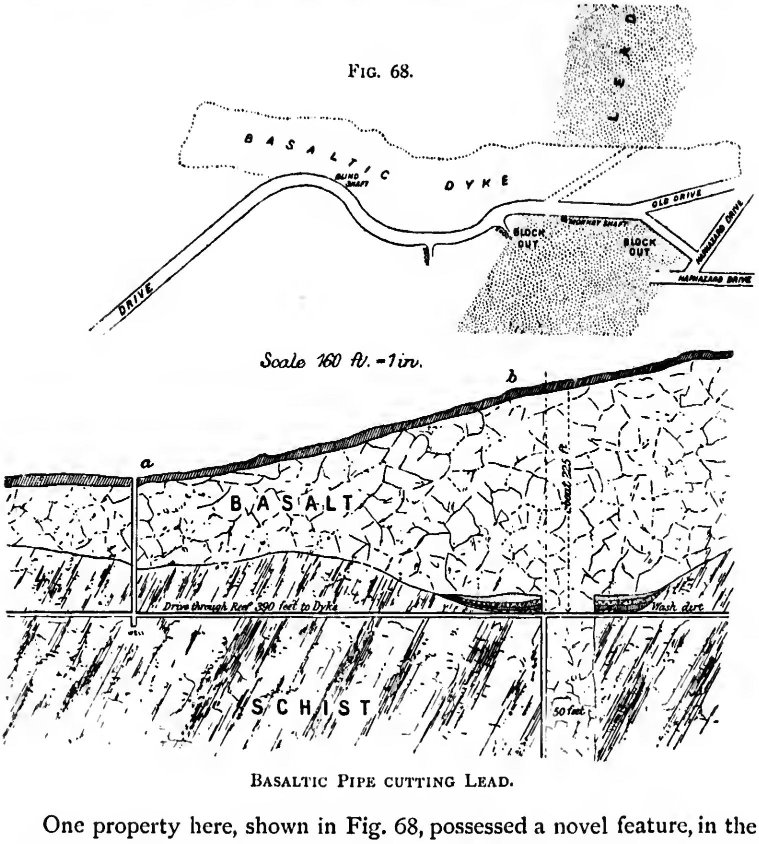
b, Palæozoic claystones, &c.; *c*, modern water-course; *d*, lead. In Fig. 67, *a*, are modern water-courses; *b*, Palæozoic clay-stones; *c*, basalt; *d*, clay and sand; *e*, sand and quartz pebbles; *f*, auriferous drift.

Fig. 67.



Deep Leads in the Daylesford District.

Fig. 68.



Basaltic Pipe cutting Lead.

One property here, shown in Fig. 68, possessed a novel feature, in the shape of a dyke or pipe of basalt, which puzzled the miners considerably.

Believing it to be an ordinary cliff, they sank down beside it for about 140 ft. at *a*, but found no bottom, and they afterwards drove through it, and discovered the bottom on the other side. The dyke is about 50 ft. thick, and the overlying basalt has a considerable thickness. It is possible that this dyke or pipe may be the outlet of an ancient crater. From a report, it seems that the shaft No. 1 was sunk to a depth of 130 ft., passing through surface soil 10 ft.; basalt 80 ft.; and Silurian slate 40 ft. A drive was then opened out and pushed 390 ft. due E. till reaching the basaltic dyke running S. E. After sinking 170 ft. down the western edge at *b*, and finding no termination of the intruded rock, the original drive was continued S.E., and the gutter found abruptly ending at the edge of the dyke.

In the lower part of the Coliban, it is noticed that wherever a basalt capping exists, the drift beneath is more or less auriferous. A shaft in that district shows,—Surface soil, 1 ft.; clay with fragments of quartz, 6 ft.; quartz-gravel, 13 ft. The bottom is pipe-clay; width of gutter, 6 to 8 ft.; thickness of wash-dirt, 1 to 3 ft.; fall of gutter, 3 ft. in every 100 ft. The wash-dirt consists of quartz boulders, clay and sand, and a portion of the pipe-clay bottom. The gold is coarse and not much water-worn.

A neighbouring shaft has cut through,—Black soil, 6 ft.; basalt, 80 ft.; stiff clay, 68 ft.; drift, 6 ft.; coarse pebbly wash, 3 ft. Width of gutter about 20 ft.; the gold not much water-worn.

At Vaughan, near the junction of Fryer's Creek and the river Loddon, the auriferous leads occur as shown in Fig. 69. The reference letters

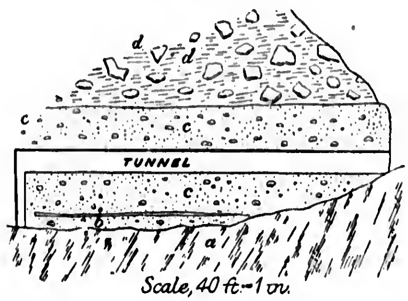
FIG. 69.

LEADS ON FRYER'S CREEK.

have the following significations:—*a*, basalt; *b*, gravel with large quartz boulders; *c*, auriferous drift; *d*, cement; *e*, alluvial; *f*, river Loddon; *g*, Kangaroo Flat.

In Fig. 70, is seen a diagram of a tunnel driven through auriferous strata on the Upper Dargo river. The "rim-rock," or edge of the ancient channel, generally to be observed in the terrace deposits occurring at various heights above the present river-beds, has been cut through to a depth of several ft. The reference letters are—*a*, Silurian; *b*, plant-bed; *c*, auriferous quartz-gravel; *d*, basalt talus. The total thickness of the gravels is about 30 to 40 ft. They consist principally of water-worn vein-quartz and pale sandstone, with a few pebbles of quartz. The gold is generally fine, and was disseminated throughout the gravels traversed by the tunnel in sufficient abundance to pay the working expenses of prospecting. The specimens found in the plant-bed have been determined as of Miocene age. The careful examination and study of these Miocene rivers becomes of immense importance, now that they are proved to be auriferous.

Fig. 70.



Lead on Upper Dargo River.

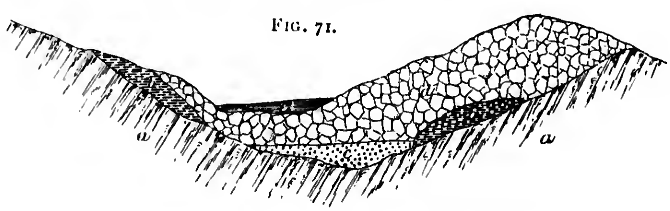
Some information concerning the auriferous Tertiary beds at Newtown Hill is to be gathered from the shafts undertaken recently in that district. The first was put down through drift and ferruginous cement, 20 ft.; bottomed on blue slate reef. No. 2 sank 67 ft. through drift and large rounded quartz boulders, bottomed on slate reef, sank in slate to 82 ft., drove in it eastwards 90 ft., jumped up 15 ft., and broke into a wash yielding fine and (so-called) "coarse" gold, the latter but little water-worn. No. 3 shaft was sunk through strata similar to No. 2, bottomed at 85 ft. on blue slate reef, opened out at 94 ft., drove eastwards 72 ft., descended 5 ft. on to slate reef at 120 ft., sank 12 ft. on to slate, and at 180 ft. sank 31 ft. on to hard slate reef. The "reef," standing on edge, had an E. slope throughout and a thin capping of auriferous drift. Other 3 shafts were sunk on the southern slope of Mercer Hill. No. 1 was through surface soil 10 ft.; brown burnt clay, 40 ft.; drift and boulders, 15 ft. Bottomed at 65 ft. on blue slate reef sloping E. No. 2 penetrated surface soil, 4 ft.; burnt clay, 50 ft.; drift with basaltic boulders, 37 ft.; fine gravel drift, 6 in.; blue slate reef, 21 ft. Opened out at 112 ft. 6 in.; drove E. 65 ft. and broke into wash, the reef still inclining E. 1 to 3; drove another 85 ft. in boulder drift, leaving the wash under foot. No. 3 section is as follows:—

		ft.
Alluvial	Surface soil	4
Newer Pliocene ..	Brown sandy clay with charred wood	45
Newer Volcanic ..	Vesicular basalt	12
Older Pliocene ..	Rounded quartz-pebble drift, with a shingle of quartz, gneiss, elvanite and bluish-black fissile metamorphic slate, occasionally streaked with quartz	7
	Drift of small rounded grains of transparent quartz, in a base of white felspathic clay ..	30
	Coarse quartz-gravel	2
	Whitish sandy clay	6
	Sand drift with quartz-gravel	18
	Sandy clay	2
		126

The material composing the older drift has undoubtedly been derived from granite and the contiguous metamorphic rocks, and the lower beds of the last section are very similar to those of the Great Western lead, where the auriferous leads rest on granite. The "coarse" gold mentioned above should probably be termed "scaly" rather. The presence of coarse gold is supposed to imply the proximity of the Older Palæozoic rocks, while fine gold may be carried a considerable distance from its source, and occur in small quantities overlying indiscriminately rocks of any formation older than the drift with which it is associated. If it can be shown that the bed-rock at Newtown Hill is a carbonaceous rock, with or without overlying Miocene beds, it is deemed useless to expect remunerative results from gold searching; but if Silurian rocks underlie the Tertiaries and Newer Volcanic beds, then, say geologists, "the principal conditions of a gold-field may be admitted to be present."

From the Stony Creek down to and through the Glenmaggie pre-emptive right, are distinct indications of an old river-bed now filled up with basalt. In the natural sections exposed, the basalt rests occasionally directly on Silurian formation, but in other places is separated from it by thick beds of intensely hard, cherty, silicious rock and conglomerate. The silicious rock thins out as the Silurian rocks rise on either side of the channel, and does not appear to occupy the river-bed, which probably contains a gravel deposit, as a few indications of such are met with. This gravel would therefore seem to be somewhat more recent than the silicious rock, and the section, if exposed, is believed to be as shown in

FIG. 71.



RIVER-BED FILLED BY BASALT.

Fig. 71:—*a*, Silurian; *b*, silicious rock; *c*, gravels in the lead; *d*, basalt; *e*, most recent alluvial deposits. The actual sections are shown in Figs. 72, 73, and 74:—*a*, Silurian; *b*, silicious rock; *b'*, gravel of apparently the same age; *c*, gravel in lead; *d*, basalt; *e*, alluvial deposits. Rolled boulders of the silicious rock, polished like glass, are frequent in some places. There is also a deposit of gravel forming hills above the level of the volcanic formation, but traceable to lower elevations and beneath the volcanic rock. This gravel may be of the same age as the silicious rock beds, or the gravel in the old channel, but as yet no definite opinion can be expressed. The modes of occurrence and doubtful character of the

relations of the gravel and silicious rock are illustrated in Fig. 73. The volcanic rock, when solid, is a dense, hard, dark basalt, but is usually much decomposed. To the south of the Glenmaggie Creek, are tracts

Fig. 72.

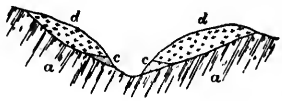


Fig. 73.

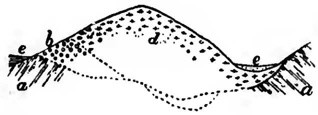
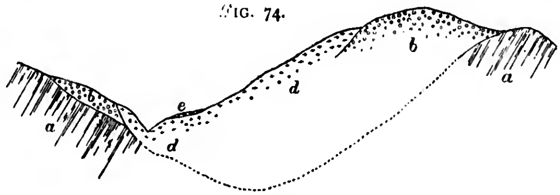


Fig. 74.



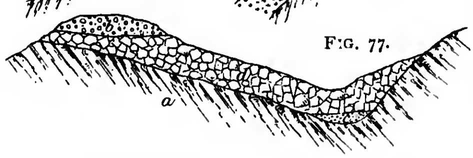
Sections at Stony Creek.

of country consisting of quartz-gravel and ferruginous cement, somewhat higher than the basaltic hills, and sloping southwards towards the plains. They sometimes rest on Silurian rocks, and are visible in one place resting on the middle Tertiary silicious rock. At the junction with the basalt, however, the surface indications so blend the characteristics of both formations that it is impossible to tell whether the gravels rest on the basalt or *vice versâ*. These two possible relations are indicated in Figs. 75 and 76. The former view is adopted, because a few miles distant a clear section is found of similar gravels overlying basalt, which is again underlaid by other gravels, as shown in Fig. 77. The reference letters are—*a*, Silurian ; *b*, gravel on hills ; *c*, gravel in lead ; *d*, basalt.

Fig. 75.

Fig. 76.

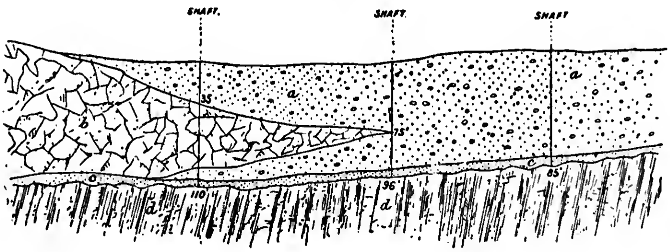
Fig. 77.



Sections at Glenmaggie Creek.

The sedimentary deposits of the Upper Pliocene period are principally a result of the arrest, overflow, or diversion of drainage due to the surface alteration caused by the lava-flows, and they are therefore chiefly noticed in the neighbourhood of volcanic rocks, whose limits they often hide. They form widespread layers of brown and mottled clay and sandy loam, with angular pieces of quartz and nodular masses of clay-marl, exceeding in places 70 ft. in thickness, and rest indiscriminately upon Palæozoic, Pliocene and volcanic rocks. Their occurrence is well illustrated in Fig. 78 :—*a*, Upper Pliocene, mottled sandy clay with

FIG. 78.

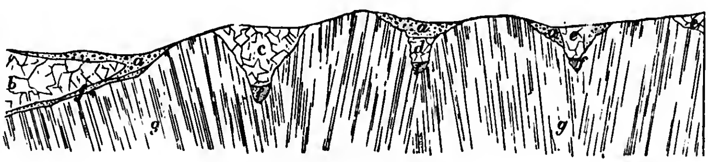


UPPER PLIOCENE LEADS.

ironstone gravel; *b*, Newer Volcanic; *c*, Middle Miocene, auriferous quartz-gravel; *d*, Palæozoic.

Fig. 79 is a sketch section of a number of lava streams met with in a distance of about 2½ miles :—*a*, Upper Pliocene (clay drift); *b*, 1st lava

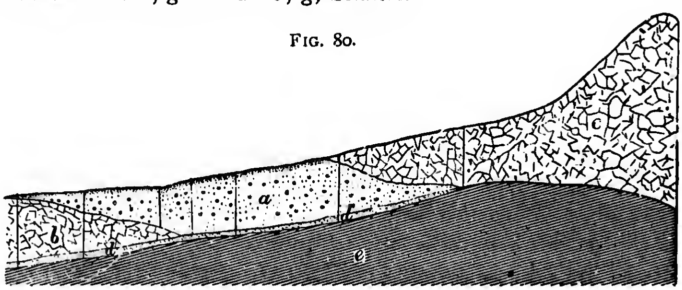
FIG. 79.



SUCCESSIVE LAVA-STREAMS.

stream; *c*, 2nd lava stream; *d*, 3rd lava stream; *e*, 4th lava stream; *f*, Middle Pliocene, gutter drift; *g*, Silurian.

FIG. 80.

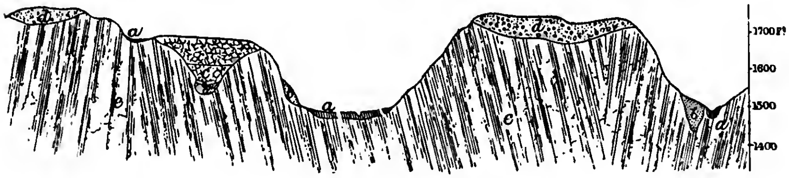


CLAY DRIFT BETWEEN LAVA-STREAMS.

Another section of about 1½ miles of ground in the same district is shown in Fig. 80 :—*a*, Upper Pliocene, clay drift; *b*, 1st lava flow *c*, 2nd lava flow; *d*, Middle Pliocene (Lewer's lead); *e*, Silurian, along the strike of the beds.

In Fig. 81 is seen a third section, about 1¾ miles in length, showing the gold-drifts or auriferous leads of the Middle Pliocene:—*a*, Post

FIG. 81.



MIDDLE PLIOCENE LEADS.

Pliocene; *b*, Middle Pliocene; *c*, Newer Volcanic; *d*, Lower Pliocene; *e*, Silurian.

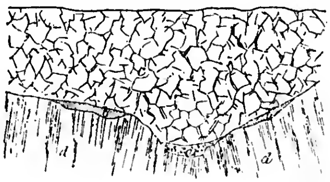
The lithological character of the basalt varies but little in different localities. Throughout the district there is the same granular dolerite, changing in one locality only to a glassy, more than ordinarily felspathic rock, and in another spot a quarry has exposed 18 ft. of porphyritic dolerite. Around the points of eruption prevail the usual varieties of cellular lava, scoriæ, volcanic ash, and breccia.

The material composing the river leads of the Middle Pliocene period, or older gold-drift, of this district is principally a coarse, much water-worn quartz and ironstone gravel, which appears to have been derived chiefly from the denuded Older Pliocene beds. As a rule, the deepest "gutter-drift" of this gold-field is poor as compared with the auriferous "reef-wash" on the higher levels. There are evidently deposits belonging to two distinct epochs, which may be classified as "newer middle" and "older middle" Pliocene. The newer middle Pliocene occupies the channels scooped out subsequently to the deposition of the older middle drift, which rests on the flanks, or forms terraces, or has often been altogether denuded away during the newer middle epoch, as represented in Fig. 82.

A good example of the occurrence of both drifts is afforded in Carter's Company's mine, Ryrie's Creek. There two narrow gutters trend northwards towards a junction with the main Spring Hill Lead. Between these two gutters is an older channel drift, crossing the others obliquely, as seen in Fig. 83. The darker portion *b* of the plan (Fig. 83) shows the older lead, which is clayey, contains ironstone gravel, and has proved highly auriferous. The lighter portion *a* represents the deep wet gravel leads of more recent formation. They are generally poor, except where they have cut through the older leads. The older drift south of Carter's shaft *c* is probably not less than 50 ft. above the level of the gutter. The main lead and the lower part of the tributary leads are covered by basalt.

Marine deposits of the Lower Pliocene or oldest gold-drift are limited to the watershed of the lower part of Slaty Creek and the upper part of Creswick Creek, where they form coverings 4 to 60 ft. thick on many of the hills, ranging in elevation from 1700 to 1420 ft. above sea-level. The material composing these drifts consists of brown clay, with quartz gravel; coarse quartz pebbles and boulders, either loosely aggregated, or bound

FIG. 82.



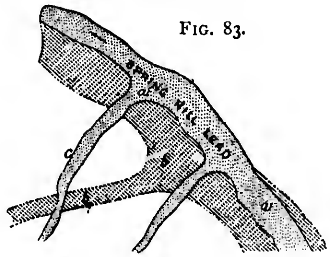


FIG. 83.

RELATIONS OF NEWER AND OLDER MIDDLE PLIOCENE.

by ferruginous cement; shingle of Silurian sandstone and ironstone. No fossils have been found in them. At two hills the boulder drift has water-worn blocks of quartz over a ton in weight and upwards of 4 ft. in diameter. The gold is coarse, rounded, and generally coated with black manganese. At Hard Hill, a nugget weighing 120 oz. is said to have been found, while pieces of 5 and 10 oz. weight were numerous. The reference letters in Figs. 82 and 83 are:—*a*, Newer Middle Pliocene; *b*, Older Middle Pliocene; *c*, Newer Volcanic; *d*, Silurian.

In one instance, in New South Wales, two leads were discovered not 100 yd. apart, parallel to each other, containing exactly similar wash-dirt, but at different levels. The one at 140 to 160 ft. had no gold, whilst that at 80 to 90 ft. yielded 10 to 15 dwt. per load. From the nature of the country, it is declared that many more deep leads will be discovered when the miners acquire a more perfect knowledge of the rocks of the district, the mode of occurrence of the auriferous veins, the conditions under which they are disintegrated and decomposed, the position of the original drainage channels, how they have been silted up, and the manner in which the ancient plains and valleys have been buried beneath an alluvial deposit 50 to 150 ft. thick. The plains of the Lachlan become alluvial gold-fields wherever gold-bearing reefs or veins, however poor, are found to occupy elevated positions in their vicinity, and where on those highlands rocks of Silurian or Devonian age exhibit traces of transmutation or disturbance by eruptive trappean rocks.

In New South Wales and Victoria, the underlying geological formation is believed to control the richness of the deep leads. Selwyn says that while the leads are richly auriferous when chiefly derived from and directly resting on Silurian rocks, "they gradually cease to be so when they become underlaid by rocks newer than Silurian." This is undoubtedly true in the majority of instances, but it is not infallibly so.

In the Canadian lead, the wash-dirt often exceeds 40 ft. in depth, which appears to be due to crevasses or fissures in the limestone bed-rock. The immense deposit contains gold uniformly throughout.

At Bushman's lead, the gold from a deep lead resting on sandstone and diorite was worth 3*l.* 14*s.* 6*d.* per oz., while that obtained from intrusive dykes and small veins intersecting the rock subjacent to the drift is worth only 3*l.* 5*s.* per oz.

It is important to notice that in deep leads the deepest ground is by no means always the best. This is easily accounted for by the fact that ancient watercourses, like modern ones, may be moderately inclined at their commencement, and then become very precipitous; the gold would lodge easily in the *bed* when moderately level, but in the *banks* when precipitous. Subsequent drifts might sweep these banks, and, becoming mixed with them, scatter a portion of their gold throughout the lead.

The Nacka Nacka Creek winds in one portion of its course through narrow alluvial flats, from which rocky hills rise on either side to an elevation of 500 ft. Resting on some of the spurs, at 10 to 70 ft. above the creek, are patches of Tertiary water-worn quartz-pebble drift, the remnants of the ancient creek bed, which once descended in an unbroken course along the valley, but which has since been cut through during the erosion and deepening of the valley. Consequently the auriferous contents of the denuded portions of the old drift have been, as it were, naturally "ground-sluiced" and redistributed in the alluvial deposits along the course of the present creek. The latter should therefore be payably auriferous, seeing that the older drift has yielded up to $\frac{1}{2}$ oz. gold per load. The section shows chocolate-coloured soil, 1 ft.; sub-angular quartz-pebble drift, containing fine gold in payable quantity, 8 ft.; stiff white clay and sand, micaceous, 4 ft.; fine and coarse rounded quartz-drift, ferruginous, yielding up to $\frac{1}{2}$ oz. gold per load, 8 ft.

At Grenfell are three deep leads which were the beds of rivers that flowed in Newer Pliocene times. They are crossed by a porphyritic dyke, and are only payably auriferous for a mile below it, and not payable immediately above it, which proves the gold to be derived from the disintegration of the dyke, or veins in it.

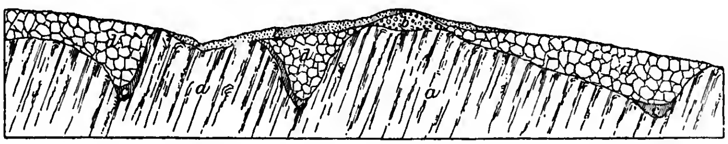
The richness of the lead is often an indication of the proximity of reefs whence the gold was originally derived, and, conversely, the nature of the rocks forming the hills indicates whether or not the alluvial deposits in the intervening valleys are likely to be auriferous.

In the Happy Valley lead, the bed-rock is crystalline limestone; the sinking is through clay and gravel with cement, 120 ft.; black clay, 12 ft.; clay and gravel, 10 ft.; coarse quartz-pebble wash, yielding 9 dwt. gold per load, 1½ ft.; quartz-pebble drift and fine micaceous clay, mingled with limestone boulders, which are often coated with black oxide of manganese and brown oxide of iron, gold averaging 1½ to 2 dwt. per load throughout the drift, 30 ft.; total 173½ ft.

Immense deposits of richly auriferous wash-dirt have been discovered in Victoria, on the sides and ledges of deep leads: only a small proportion of the gold of the deep leads of Ballarat was taken from what is termed the lead proper—deepest channel or "gutter,"—but by far the greatest quantity of gold was subsequently found to have lodged on either side of the ancient river banks, what is familiarly termed in the deep alluvial districts "reef-wash."

Subjoined is a sketch-section (Fig. 84), of the Wallaby diggings in Victoria. The reference letters indicate as follows:—*a*, Palæozoic;

FIG. 84.



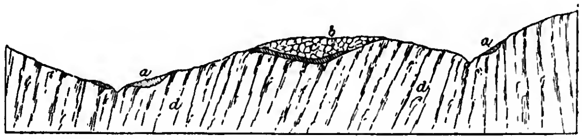
SKETCH-SECTION OF WALLABY DIGGINGS.

b, Older Pliocene; *c*, Middle Pliocene; *d*, Newer Volcanic; *e*, Upper Pliocene. The gold in these leads has been derived from quartz veins traversing the ridge, and which have been exposed by the alluvial operations and since worked.

In the neighbourhood of volcanic centres, it is usual to find that the greatest extent of the latest Tertiary deposit occupies places on and around the basalt boundaries where the clay drift fills up the inequalities in the surface caused by the lava-streams. In most of the watercourses which are scooped out on, or adjacent to, the sites of Middle Pliocene leads, are found Upper Pliocene drift banks, consisting in great part of the redistributed material of the denuded older drift. Red, brown, blue and mottled clays, with angular quartz fragments, form the matrix, with which are mixed up well-worn pebbles and boulders of quartz, and shingle of slate and sandstone. In many places, where a layer of lava has been intersected by later erosion, as in Fig. 85, pebbles and larger masses of completely-rounded basalt form a not inconsiderable adjunct to the drift. The reference letters are :—*a*, Upper Pliocene (recent gold-drift) ; *b*, Middle Pliocene (older gold-drift) ; *c*, Newer Volcanic ; *d*, Palæozoic.

It often happens that accumulations of débris make it impossible to

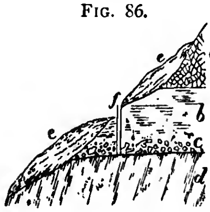
FIG. 85.



UPPER PLIOCENE DRIFT BANKS.

find the exact level at which to drive into the gravel of a deep lead. The first object should then be to find the contact of the gravel and bed-rock *in situ* in the deepest part of the lead, and this can only be done by experimental cuttings and shafts, whose site must be selected according to the appearances of the ground, the exposures of clay and sand beds above the gravel, &c. These difficulties, and the method of dealing with them, are illustrated in the accompanying sketch-section, Fig. 86. Once the actual bed of the lead is found, subsequent operations are simple enough. The reference letters indicate :—*a*, basalt ; *b*, sand, clay, &c. ; *c*, gravel *in situ* ; *d*, bed-rock ; *e*, fallen débris ; *f*, prospecting shaft.

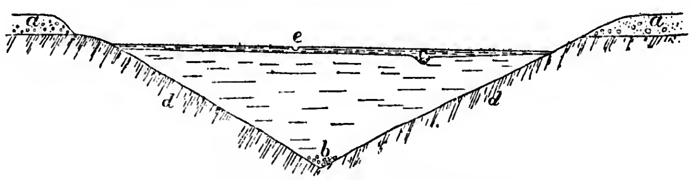
FIG. 86.



LEAD HIDDEN BY DÉBRIS.

Fig. 87 shows an instance of three pay-channels at different eleva-

FIG. 87.



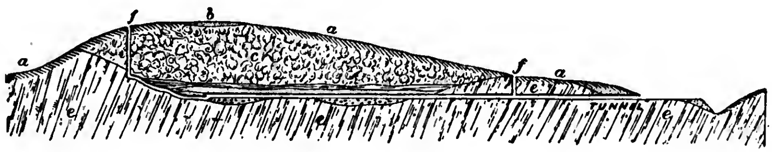
THREE PAY-CHANNELS AT DIFFERENT ELEVATIONS.

tions :—*a* is the oldest drift, worked for gold ; *b*, an auriferous deep lead, 200 ft. or more in depth, resting on Silurian bed-rock *d* ; *c*, auriferous shallow lead, about 12 ft. in depth, and resting on a false bottom ;

e, watercourse. The deep lead, in the lower part of its course, is covered by Newer Volcanic rock.

Fig. 88, on a scale of 160 ft. = 1 in., is a section showing the Tangil lead, as proved in the workings of the Tangil Gold-mining Co., about 1½ miles S. of Tangil township :—*a*, surface soil; *b*, Pliocene drift above

FIG. 88.



TANGIL LEAD.

volcanic; *c*, volcanic (decomposed basalt); *d*, Miocene clays, gravels, &c., beneath volcanic; *e*, Upper Silurian; *f*, shafts.

In California, the modes of occurrence of the gravel deposits are various. Sometimes they exist in well-defined ancient river-beds under a capping of basalt, which has filled the channels of the rivers of past ages; again, they appear in isolated mounds or hillocks, evidently the remains of such channels, which, being unprotected by a covering of lava, have been broken up by the action of the elements; also, in basins or flats which have received and held the wash of these disintegrating rivers; and in low, rolling hills, near the base of the Sierras, and beyond the reach of the lava-flow.

One of the most remarkable and important leads in America is that

FIG. 89.

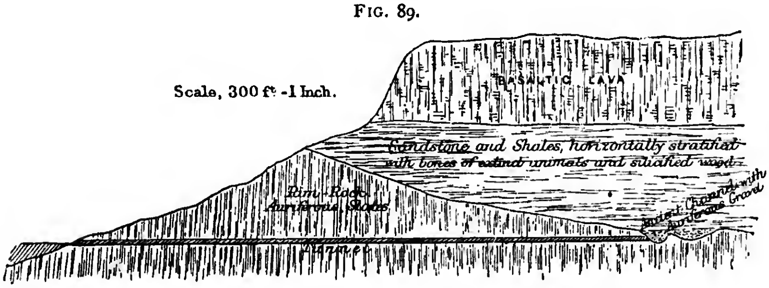


TABLE MOUNTAIN.

beneath Table Mountain in Tuolumne county, which is represented in the accompanying section (Fig. 89).

Many auriferous gravel deposits exist in various parts of California, particularly near the limestone belt, in basins or flats. These, like the detrital matter in the foot-hills, are probably the result of secondary deposition in a recent geological epoch—the effects of the distribution by water of the ancient beds, and the denudation of the surrounding country.

The dead rivers of California, so far as known, are on the western slopes of the Sierra Nevada, and 500 to 7000 ft. above the sea-level. They are all auriferous, and have been sought for and examined. The largest and richest of them all is the "Big Blue" lead, which has been traced with certainty for a length of 65 miles, and is believed to have been followed for a distance of 110 miles. Its course is S.S.E., about 30 miles west of and parallel with the main divide of the Sierra Nevada. The elevation is about 5000 ft. above the sea at one end and 2800 at the other, giving an average fall of 33 ft. per mile. The live or modern rivers of the Sierra run at right angles to it, cutting cañons 1500 to 3000 ft. deep, and separated by ridges 3 to 6 miles apart, and as high as the cañons are deep. The Blue lead runs across these ridges at 200 to 1000 ft. below their summits, without in any way altering their appearance, or giving any clue to its whereabouts. It was discovered in detail by the same process which has revealed the existence of most deep leads—surface washing. The miners found that the modern streams were richly auriferous up to a certain point, increasing as it was approached, but ceasing when it was passed. These points were more or less in a line on the different streams, and by following up various indications, the lead was ultimately struck in several sections, and tunnelled out.

The auriferous deposit is composed of gravel, boulders, clay and sand, varying from 100 to 300 ft. in depth, and lying in strata distinguished from one another by differences in colour, in the size of the boulders and gravel, and in the number and size of the particles of gold. The predominant colour is bluish-grey, lightest at the top and deepening to a bright indigo at the bottom (hence the name). This colour is supposed to be derived from the bed-rock, the grinding away of which afforded the pigment to dye the quartz, &c., sulphides of iron assisting to make the colour fast. A reddish tinge in those places that have long been exposed to the air shows the presence of iron. The material composing the boulders, gravel and sand is almost exclusively quartz. The bed may be roughly estimated at ½ mile wide throughout, and the gravel beds some 200 ft. thick. All the pebbles, many of which weigh a ton, and some even 20 tons, are worn perfectly smooth. The gold is coarser, and contains more silver at the bottom than at the top. The finer grains are in the upper strata, and as they have a larger surface proportionately, the silver is eaten out by the sulphurous acid which is developed in the gravel by the oxidation of pyrites. The whole deposit is formed as in existing rivers. There are banks, bars, eddies, falls, rapids, and riffles. There is much gold in the eddies, and little in the rapids. The space between the boulders is filled up with sand, clay, and gravel, which contains the gold. The bed is of slate rock, and the banks are 50 to 300 ft. high; but there are few places where they have been examined, as the gravel has rarely or nowhere been washed away from the whole width of the bed. There is no doubt that the cause of the death of the Big Blue river was the upheaval of the Sierra Nevada range. Many of the hills pierced by the Big Blue lead are capped with basaltic lava, which covered much of the country from near the summit of the range to about 3000 ft. above the sea. It would seem that the river first silted up its bed; that the mountain range then began to rise, and volcanoes broke out along it; that the lava from the latter ran down and covered the land to the line of the dead river and beyond it, and finally, that the mountains rose still higher, and the streams running down their sides cut through and made deep cañons in the lava, and washed away a great portion of the ancient river deposit, scattering its gold among their own alluvia.

The upper quartz gravel, some 250 to 300 ft. thick, of which the main body of the Tancow or Butte county Table Mountain is composed, consists entirely of quartz pebbles and quartz sand, and carries very fine grains of gold. The two lower strata, however, known as the "rotten boulders" and the "blue lead" or gravel, are mixed more or less with different rocks, consisting in the former of clay-slate, and in the latter of talc-schist. Both these strata are very rich in gold, and average 5 to 25 ft. in thickness, each. The "rotten boulders," so called on account of their softness, have so far been the chief resources for the miners, as they were easily reached. This stratum is said to be peculiar to the Tancow deposit.

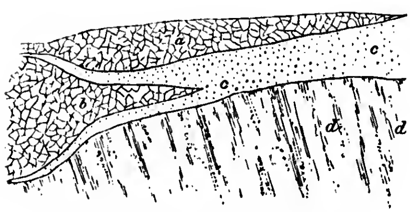
Hitherto, attention has been given to leads covered with only one layer of basalt, or with no volcanic covering at all; but in some places there are 3 and even 4 distinct layers of basalt overlying the leads. Though 3 or 4 strata of basaltic rock may be cut through, it is not certain that they always represent separate and distinct outflows. If the line of separation contain a bed of waterworn gravel, however, the disconnection of the two basaltic beds may be considered established; but if the material intervening be simply white or red clay, with a few fragments of angular rocks, the phenomenon will more probably be due to decomposition of the basalt, for it is known that the rock decomposes *in situ* where water finds its way through it. The true bottom is never basalt, and the richest lead is almost always that lying beneath the lowest volcanic stratum.

The following tables of strata are taken from sections of formations with a plurality of basaltic beds :—

		ft.	in.
1.	Three courses of basalt, separated by layers of clay ..	200	0
	Black and blue clay with quartz fragments	10	0
	Quartz gravel and boulders ..	8	0
	Bottomed on sandstone at ..	218	0
2.	Alluvial	15	0
	Basalt	22	8
	Clay, &c.	16	6
	Basalt	72	6
	Reef	0	7
		127	3
3.	Alluvial	20	9
	Basalt	16	0
	Alluvial	17	3
	Basalt	66	2
	Alluvial	10	4
		130	6
4.	First rock	135	0
	Clay	10	0
	Second rock	80	0
	False bottom	15	0
	Drift	10	0
	Wash-dirt	6	0
		256	0
5.	Clay	11	0
	Basalt	28	0
	Red clay	8	0
	Black clay (extremely light) ..	15	0
	Basalt	92	0
	Black clay	3	0
	Green stuff, like reef	9	0
	Sandy fine drift	4	0
	Basalt	12	0
		182	0
6.	Surface soil	9	0
	Rotten basalt	20	0
	Massive blocks of basalt	14	0
	Red sandy clay	8	0
	Basalt	51	0
	Gravel and clay	13	0
		115	0

7. Basalt, 36 ft. ; red clay, 6 ft. ; basalt, 59 ft. ; clay, 4 ft. ; total, 105 ft.
8. Surface earth, 7 ft. ; basalt, 130 ft. ; stiff clay, 18 ft. ; basalt, 29 ft. ; mixed clay, gravel and drift, 83 ft. ; wash-dirt, 5 ft. ; total, 272 ft. Width of gutter, 100 to 250 ft. ; depth of wash-dirt, 4 to 7 ft. The wash-dirt was a dark-coloured coarse gravel, mixed with clay, containing large quartz boulders, charcoal, and decayed wood.
9. Basalt, 160 ft. ; very hard sandstone conglomerate, 20 ft. ; second layer of basalt, containing a large quantity of water ; layer of grey clay ; and a layer of black clay, so largely composed of vegetable matter as to resemble coal in appearance and structure. On the Ballarat gold-field, this black clay nearly always overlies the "gutter," and its presence used to be regarded by the miners as a certain indication that the shaft would bottom in or near the gutter.

FIG. 90.



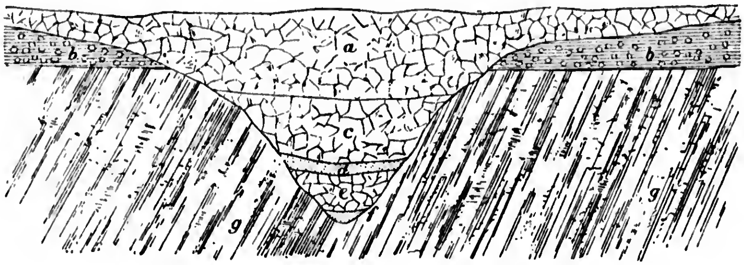
LAVA-STREAMS AT HAWKINS' LEAD.

Fig. 90 is a sketch-section showing the occurrence of lava-streams at the Hawkins' lead :—*a*, 1st rock ; *b*, 2nd rock ; *c*, clay ; *d*, schist.

Fig. 91 is an ideal section showing the position of the Durham lead under the Mount Mercer plains :—*a*, Mount Mercer lava-flow ; *b*, Older

Pliocene; *c*, Durham lead (2nd rock); *d*, middle drift; *e*, Durham lead (3rd rock); *f*, lower drift; *g*, Silurian bed-rock.

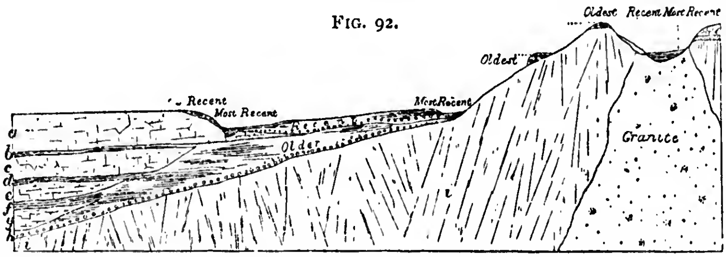
FIG. 91.



DURHAM LEAD UNDER MOUNT MERCER PLAINS.

Fig. 92 is a sketch-section showing the occurrence of the strata in the celebrated Ballarat district, Victoria:—*a*, 1st rock or lava; *b*, clay; *c*, 2nd rock; *d*, clay; *e*, 3rd rock; *f*, clay, sand, &c.; *g*, 4th rock; *h*, clay, sand, and gravel (gutter drift); *i*, Lower Silurian bed-rock.

FIG. 92.



SKETCH-SECTION OF STRATA AT BALLARAT.

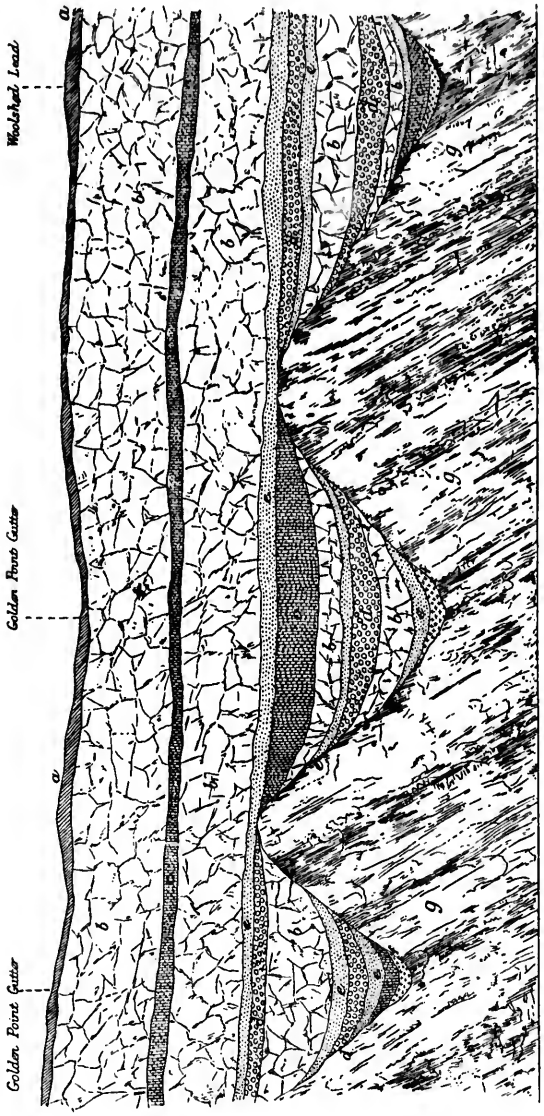
Fig. 93 is a section across the two arms of the lead known as the Golden Point Gutter, and the Woolshed lead, on the Ballarat goldfield:—*a*, surface soil; *b*, basalt; *c*, black or red clays; *d*, sandy drift; *e*, light-coloured clays; *f*, auriferous drift; *g*, Palæozoic bed-rock.

Special features or peculiarities are constantly being noted, and should receive the most careful attention. Some will be found scattered already throughout this chapter, but others remain to be mentioned.

At Ballarat, the reef was generally pipe-clay; but in some places, sandstone bottom was found: in the latter case, the lead was much poorer than in the former, that is to say, it had not offered such great obstruction to the passage of the gold down stream.

It is commonly believed that where dead-river beds meet, the wash-dirt must necessarily be rich and abundant, and it is usual for miners to rush to secure ground where leads are supposed to unite. Where all

Fig. 93.



Section across Golden Point Gutter and Woolshed Lead.

the leads tending to the junction are known to be rich, these expectations are not likely to be disappointed; but, in most instances, the miner should carefully ascertain the character of the main leads and their tributaries. A very rich lead is often rendered worthless by the influx from a tributary, of great quantities of water charged with *non*-auriferous sands and gravels, derived from a large drainage area barren of gold-bearing rocks. The greater force of united currents, too, will scatter over a wide surface and through a great mass that which was before confined within smaller limits.

Where the Palæozoic rocks are exposed by the denudations which have swept away the basaltic lavas, it will be possible to reach the gutters of the deep leads with exceptional ease.

An instance has been known of a deep lead trending in the opposite direction to the flow of the modern stream above it, that is to say, that the dead river unmistakably ran northwards, while the living one flows southwards. This is, of course, due to alterations in the configuration of the country.

In trying to sink through a false bottom on one claim, there was discovered, at a depth of 90 ft., a vein of wash-dirt almost perpendicular, or dipping slightly, like a quartz reef.

There is a peculiarity noticeable about the wash-dirt in a lead in Montana, that, wherever it is composed of quartzite and quartzite slate, it pays well, but where it is largely made up of granitic rocks, little or no gold is found in it.

Where the lead becomes very narrow, dips fast, and is enclosed between steep walls, the gold will be very sparingly distributed in holes and behind ridges, and will be coarse in size.

On the Creswick gold-field, in Victoria, it is observed that, as a rule, the deepest gutter drifts (Newer Middle Pliocene) are poor as compared with the reef-washes (Older Middle Pliocene) of the higher levels. This seems to show that the older drainage courses have been the receptacles of gold derived from a much greater denudation of the surrounding country than those of the more recent period which now occupy the lower levels.

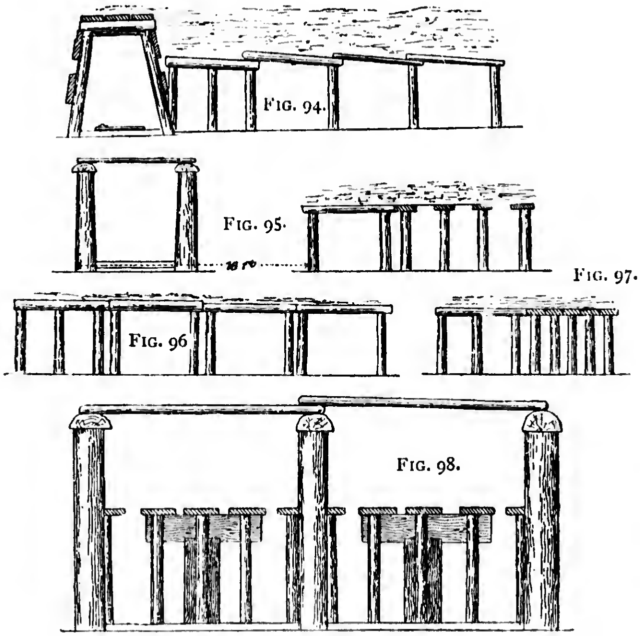
The occurrence of auriferous drifts between layers of volcanic rock has previously been noted in a few instances; but it is rare that the gold exists there in very payable quantity. Krausé, however, draws attention to a specific place where such a deposit is yielding ½ dwt. of gold to every machine-ful of wash-dirt.

Modes of Working.—It is deemed unnecessary to occupy space here with a discussion of boring, shafting, tunnelling, and other matters incidental to mining in general, as such subjects have been already sufficiently well treated in other works, notably André's treatises on Mining

Machinery, and on Coal Mining. Special attention may be directed to his description of Chaudron's shaft-sinking machine, a Belgian invention of great value. There remain for consideration a number of points, more or less important, having a special bearing upon the extraction of gold from deep leads.

The method of reaching the auriferous stratum or wash-dirt on the bottom or banks of the lead is not always the same. In places where the beds of the modern streams are lower than the level of the wash-dirt, horizontal tunnels will generally, though not always, be found the most economical. These must be driven with such a slope upwards from the mouth that the water accumulating in the tunnel will naturally find an outlet by running along the bottom of the tunnel. In most cases, the tunnel requires some sort of timbering to support the sides and roof. It is quite impossible to give the slightest clue to the cost of tunnelling, as it depends upon so many conditions, which vary in every instance. The wetness or dryness of the ground; the degree of hardness of the rock; the facilities for, or difficulties in the way of, procuring suitable timber for props, cap-pieces, and slabs, where necessary: all tend to increase or decrease the cost, just as the circumstances are favourable or otherwise.

The following description of a system of blocking-out followed in the alluvial mines at Huntly and Bagshot, Bendigo, during the past 7 years, is taken from a special report on the subject by H. B. Nicholas, Inspector of Mines at Sandhurst. He says that no accident has occurred from a fall of ground since the system was first introduced in these mines. The main and block drives are timbered, as shown in Figs. 94 and 95. The blocks are commenced at 16 ft. from the main drive, as that distance is considered necessary for the security of the permanent works. In Figs. 94 and 95, the laths overlap and are placed, in dry ground, the distance apart shown; whilst in very soft or wet ground, each lath stands separately on its own timber, and close together, as shown in Figs. 96 and 97. In each case, the laths and props decrease in size from the drive towards the back of the block, because it is considered desirable to allow the ground at the back of the block to collapse as soon as possible after the "bottom" (wash-dirt) is taken off. The maximum thicknesses of the props and slabs used near to the drives are 5 in. and 1½ in. respectively, and the minimum thicknesses at the back of the blocks are 1½ in. for props and ¾ in. for slabs. If the block or roof stands up any time, is swaying, or, to use the miners' term, "talking," the props are knocked from under the back laths, and the block is let down, thus relieving the front laths of the weight, and saving the drive from crushing. This method of blocking is the safest and cheapest way to work alluvial ground. The safest because each lath stands on its own timber, and there is no shaking of the roof by driving laths, and no fear of knocking the timber out; and the cheapest, because the timber is lighter to handle, cheaper in price, no false sets are used, nor anything cumbersome. If the ground is very soft or heavy, the blocking drives are put in first, and the miners then block back on both sides, and let the ground down in working back. In dry ground, they take the block up on one side of the drive, as shown in Fig. 94, and bring it back on the other, always letting the roof down at the back.



BLOCKING-OUT DEEP LEADS.

In driving, the sets shown in Figs. 94 and 95 are considered the best; if the ground is very heavy, the cap of the set, over which the laths are to be driven, is dogged with two strong iron dogs to the back sets which have weight, and a horned false set is used. This is very quickly done, if, when the set is made, an auger-hole is bored in each end of the cap; it will then be ready for dogging, and when the set is up the dogs are easily withdrawn. In driving through heavy ground, 4-ft. slabs are generally used, and occasionally slabs of 4 ft. 6 in. In blocking-out, however, 4-ft. 6-in. slabs are always used.

When the alluvial drift in which the mining operations are carried on becomes very heavy, between each set a "dummy" prop and cap are added. The props are 8 to 12 in. diameter, and the caps used are 2 to 3 ft. long by 6 to 8 in. diameter; these are put in to protect the drive, as shown in Fig. 98.

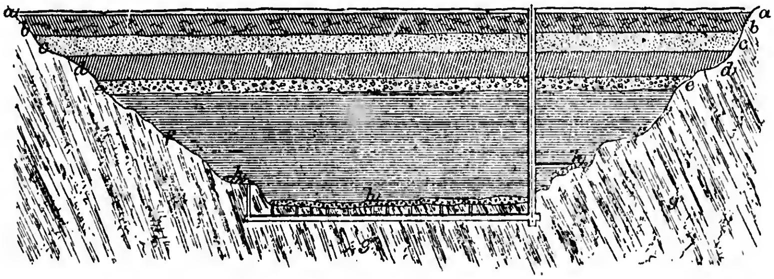
In working very soft ground by this system, and supposing the miner to be in the face or commencing to block out, he takes a lath 6 to 8 in. wide and a prop about 2 in. diameter, each of the required length; he places the prop under the centre of the lath, which he holds with one hand against the face, and, with a light pick in the other hand, he scratches away the drift (sand) in front of the lath until it is in the full width, then, placing a prop under each end of the lath, he removes the centre prop, and takes out the wash-dirt. One manager of long experience in this division, in describing this method of working soft ground, says, "I have seen miners put in laths by holding the centre in one hand, forcing the lath against the face, and with the fingers of the other hand work out the sand until the lath was in its place, then prop the ends, remove the centre, and take out the wash." He further mentioned, to show the superiority of this system as compared with the old one, that "he had seen a miner working in ordinary ground, using 2-ft. 9-in. props, excavate a block 4 ft. wide by 16 ft. in length in 8 hours, and, at the same time, as his work progressed, he put in 16 laths and 20 props. This was in dry ground, where the laths lapped, and were placed 1 ft apart." Under the old system of blocking-out, an excavation 4 ft. wide by 8 ft. long is considered a good 8 hours' work.

Where the tunnel would have to be of great length in order to reach the deposit, it may often be found less expensive to sink a shaft directly on to the lead, though that necessitates increased machinery for raising the wash-dirt to bank, and for draining the mine of water, by pumps or other well-known contrivances. When there is no convenience for a horizontal tunnel, a shaft becomes a necessity. In opening new and unknown leads, it is advisable to bore first, in order to find the *position* of the lead and the most suitable spot for a shaft, then to sink a shaft to ascertain the *character* of the lead, supplementing it with tunnels or drives in different directions if considered desirable. Fig. 99 illustrates the method of sinking and driving as carried out on the South Lead Gold-mining Co.'s property, at Forbes, New South Wales, sketched by De Lacy Richards, R.N., from pencil delineations by Phillip Davies, to whom the author is indebted. The reference letters indicate: *a*, surface soil; *b*, clay with limestone clinkers; *c*, very fine drift containing much water; *d*, rotten clay; *e*, gravelly drift; *f*, hard brown clay; *g*, slate; *h*, wash-dirt.

The Table mountain in Tuolumne county, California, already described (see p. 935), was first worked by horizontal tunnels, costing enormous sums of money, on account of their great length. In some cases, these tunnels have been discarded for mining purposes, and allowed simply to serve as drains for the workings, while diagonal tunnels or inclined shafts have been put down on the face of the rim-rock and between it and the basaltic capping. Tunnels or drives radiate from the foot of the incline.

The manner in which the pay-dirt is worked when it has been reached by the tunnel shaft also varies according to circumstances. Perhaps the

FIG. 9?.



SINKING AND DRIVING ON DEEP LEADS.

most general plan is that known as "drifting." This consists in working out the auriferous gravel by a system of tunnels and galleries, and raising it to the surface so as to run it through sluices or cradles for extracting the gold. In this case, nothing but the gold-bearing earth or gravel is removed. The main tunnel is carried on upstream and the galleries are run to either bank (or rim). The gravel is worked out, and the galleries are generally allowed to fall in as the work advances, the main tunnel being secured by timbering. Raymond says that the depth of gravel which it is found will pay to work by this system is 3 to 5 ft., but it is obviously impossible to lay down any hard-and-fast rule.

At the Bald Mountain in California, the sluice for washing the deep-lead gravels is 6600 ft. long, 17 in. wide, and 18 in. high, paved with blocks 16 in. square and 4 in. thick. The gold, being coarse, settles in the interstices between the blocks. The usual head of water is 100 to 150 in. The flume is cleaned up in sections twice a month, and a general clean-up is made twice a year, when the worn-out blocks are turned over or replaced. A set of blocks will last about 10 months, but during this time they are turned over. The flume is built on a grade of 6 in. in 12 ft. The main tunnel is 6 ft. 3 in. wide at the bottom, 3 ft. 8 in. wide at the top, and 6 ft. high. It is substantially timbered, and laid with iron tramway-rails. The cars are $4\frac{1}{2}$ ft. long, 2 ft. wide and $2\frac{1}{2}$ ft.

high, holding 1 cub. yd. of loose dirt. The ordinary car-load is about 16 cub. ft. or 1 ton, and, according to the ideas of Californian miners, the pay-dirt should yield 2 to 4*s.* per car-load to make drifting profitable; 1 cub. yd. of rock or hard gravel, &c., will generally occupy about 2 cub. yd. when broken down. "Drifting" is compulsory where there is not sufficient water for hydraulicing, as well as enough fall and accommodation for the immense masses of tailings caused by that process.

Multifarious devices are employed for conveying the dirt along the drives to the shafts:—throwing it by shovels, carrying it in buckets, wheeling it in hand-barrows, running it in trucks travelling on rails, and either emptying on flats for the dirt to be shovelled to the hoisting apparatus or fitting into cages and raised bodily to the surface. The trucks may be pushed by hand or dragged by ponies, mules, or donkeys, as circumstances dictate. For turning trucks from one drive into another, a plain sheet of iron is preferred to a turn-table. Either water or steam power may be used for raising the dirt, which is usually tipped into enormous receptacles placed at such a height above the ground as is rendered necessary by the fall of the sluice, which must be sufficiently great to carry away the tailings. Sometimes the water raised from the mine is utilized in the sluices; but objections to this plan have already been mentioned (p. 902). Where a considerable fall is necessary, it is sometimes obtained by building a tower, to the top of which the cars are run on inclined planes, and there tipped into the sluice. Occasionally these inclined planes are made to radiate to different parts of the working, where the top soil is stripped off as in a shallow placer.

The wash-dirt obtained in driving is either sluiced or puddled, in fact the process becomes identical with that of the shallow placer mining. Sometimes the clearings-up of puddling-machines, pebbles, quartzites, &c., are treated by the ordinary cradle; the heaps are first sifted, and the fine stuff brought to water and cradled.

When the supply of water, amount of fall, &c., admit of hydraulicing, as described in the next chapter, it is preferred to drifting, as being less costly and capable of turning out much greater quantities. In this system, shafts are unnecessary, unless it may be now and again for ventilating purposes. The water is introduced at the point where the gravel is being taken out, and the tunnel is made into a sluice, through which all the dirt, auriferous or otherwise, must pass. In one deep lead in California, the gravel is dropped down a shaft 200 ft. deep into the main tunnel. Thence it is washed through 8000 ft. of sluices in the tunnel, and an additional 4000 ft. outside, over the creek-bed and undercurrents to the South Yuba, where it is swept down the great cañon into the valley below. Water for power is brought through a sheet-iron main, 15 in. to 7 in. diameter, and branches (7-in.) aggregating 9960 ft.

in length, and discharged against "hurdy-gurdy" wheels, 17 to 21 ft. diameter, under pressures varying from 285 to 549 ft. The water-pipe was put together stove-pipe fashion, and gave little trouble by leaking or otherwise.

In a deep lead at You Bet, Nevada county, the cement is overlaid by gravel which is richly auriferous. The cement is being extracted by drifting, and put through sluices. The timbers are taken out as fast as the cement is worked out, and the superincumbent gravel is allowed to fall in, the intention being to treat this gravel by the hydraulic system, when the cement is finished. The cement is crushed in a mill of 8 stamps of 850 lb. each, arranged in two mortars. The lift is 12 in.; 56 drops per minute; discharge, 5 in. above dies; sieves made out of No. 18 iron with $\frac{1}{8}$-in. punched holes; size of sieves, 48 in. by 16 in. Most of the gold is caught by mercury in the mortars, the rest by copper plates below. The hoisting and pumping are done by the same water-wheel that drives the stamps.

A useful hint for taking water from a river, without the risk incidental to a high dam, consists in digging a cut along the side of the river large enough to contain a box-flume, which will be covered with rock and dirt, leaving the bank of the river in its natural state. Around rocky points, a stone wall is commenced far enough down the banks to get a perfectly solid foundation. This is continued up to the top of the ditch, and is made 4 or 5 ft. thick, then an inner wall 2 ft. wide and 2 ft. distant from the outer one is built 4 ft. high from the bottom of the ditch; clay is then tamped between these two walls, so as to make the ditch watertight.

Ventilation.—A few of the simplest modes of ventilating are worthy of passing notice. One of the earliest plans adopted for ventilating a shaft was by means of a calico windsail, such as is used on ships for taking air down into the hold, suspended from a pole, the wings kept open by means of cords fastened to pegs, and the pipe hanging down the shaft. This apparatus is not capable of forcing air along the drives. The "fanner" consists of a spindle furnished with wings, which is made to revolve by an endless cord passing round the wheel on the spindle, and another which is turned by hand, water, or steam power. The piping may be of calico, tin, or galvanized iron. A third plan consists in dividing the shaft by a partition running down the centre and parting the main drive in a similar manner. In order to clear the drives of foul air, a quantity of water is thrown down one compartment of the shaft, so as to displace the air and force it through the drive and up the other compartment of the shaft. Other plans which have been used are:—carrying air-drives in the same direction as the main drives at a higher level, and constructing openings at various points from one drive to the other ; building a furnace underground in connection with the air-drives ; erecting an air-stack over an air-shaft, connected with one of the compartments of the main shaft. Besides these, there are the air-duct, and air-engines of all descriptions.

Apparatus.—The gold-extracting apparatus generally used where the deep leads are worked by drifting consists of puddling-machines, sluices, &c. At one large Victorian works, 2 puddling-machines each 16 ft. in diameter, and a sluice-box 60 ft. long and 10½ in. wide, were used, the average quantity of wash-dirt put through each machine per 24 hours being 300 trucks or 60 tons. At another lead on the Ballarat gold-field, the plant consisted of 5 iron puddling-machines, 2 sludge-machines, 2 buddles, and 2 sluices. The sluices were for separating the gold from the dirt after it had been through the puddling-machines, and the sludge-machines and buddles were used for saving the fine gold carried off in the sludge from the puddling-machines. The sides and bottoms of the puddling-machines are sometimes covered with ⅛-in. sheet-iron. In a third instance, are 4 cast-iron puddling-machines, fixed so as to form a square ; each machine is 16 ft. 6 in. in diameter and 2 ft. 6 in. deep, and worked by Hunt and Opie's patent chain and pulleys. Above the machines is a stage connected with the brace, which is about 40 ft. above the surface, and upon this stage the trucks are run and the dirt emptied into the machines. In the bottom of each machine are two cast-iron doors, about 1 ft. 6 in. × 2 ft., hung so as to open below, for the purpose of cleaning them out. These doors are fastened with 4 screws, and when the machines have been filled and the dirt sufficiently puddled, the doors are opened from below, a barrow and scrape are attached to the machinery, and by means of these the dirt is cleaned out of the machine through the doors in about 30 minutes. Below the machines is the sluice-house, where are 4 sluice-heads, one under each machine; these lead into the centre or main sluice. The dirt, when puddled, falls through the holes or doors in the bottoms of the machines close to the sluice-heads, so that the men can conveniently feed the sluice. In the centre sluice is a fork worked by machinery, for the purpose of separating the dirt. The four machines are tended and cleaned out by 2 men in each shift, and all the dirt is sluiced during daytime by 2 men and 1 boy. The stones taken from the machines as the dirt is puddled, are passed through the centres of the machines, so that no trucks or barrows are required on the machine floor. The two iron sludge-machines are about 14 ft. in diameter and 2 ft. deep ; the sludge as it leaves the puddling-machines passes into them, and the sand taken from these machines is passed through a sluice and over a blanket surface ; the stuff washed from the blanket is put through the amalgamating barrel.

Yields.—A few figures concerning the yields of gold from various deep leads may be interesting, though affording no guide to the possible returns of any new field of operations. One field of 20 acres produced 16,440 oz. of gold; the average at another diggings was 2 dwt. 22 gr. per ton; at a third, 1 to 1½ dwt. per load; at a fourth, 5 dwt. per ton; at a fifth, 6 dwt. per ton; at a sixth, 15 dwt. per load. In a seventh instance, one mile of lead yielded 170,000 oz., equal to 32 oz. per lineal ft. These figures all refer to Victoria, and are on the authority of Brough Smyth. In California, 50 c. (say 2*s.*) per cub. yd. seems to be the average value of the wash-dirt in the deep leads; but Raymond mentions four Companies which made respectively $10·80, $8·10, $9·45, $7·38 per sq. yd., which gives an average of 95 c. (3*s.* 11½*d.*) per sq. ft. of ground 4½ ft. high, or $5·70 (23*s.* 9*d.*) per cub. yd. of gravel.

In one of the Government Surveyor's Reports on New South Wales, the dimensions and prospects of a particular lead are succinctly placed before the reader. The width of the lead is about 200 ft.; thickness of wash-dirt, 3 ft.; yield of gold, low—5 dwt. per ton; every 100 ft. run would produce 60,000 cub. ft. of wash-dirt, or 2500 loads of 24 cub. ft. to the load, which, at 5 dwt., would yield 625 oz. or about 2500*l.* per 100 ft. This authority says that deep leads can be worked (in New South Wales) at a cost of about 10*s.* per load, including puddling the wash-dirt by steam-power; 30 to 40 men could work on a lead 200 ft. wide, and 30 men should produce 360 loads per week, yielding 180*l.* clear profit per week, after paying 10*s.* per ton for working expenses. Hundreds of thousands of tons of wash-dirt have been worked at Ballarat, in Victoria, for considerably less than 10*s.* per ton.

CHAPTER V.

HYDRAULICING.

Origin.—In the last chapter were discussed the features of deep leads, and the means adopted for extracting their gold by the aid of hand-labour and moderate supplies of water. But hundreds of square miles of auriferous gravels exist whose gold is so fine and so widely distributed that its extraction could not by these means be made to pay. The disintegrating and removing power of water is patent in every-day life; it has been the great agent in forming the deep and shallow placers; and without it the modern miner would be unable to separate the gold from the baser bodies with which it is mixed up in the leads, and in quartz veins. A sharp-witted American, foreseeing that the effects of an ordinary stream of water, acting by its own gravitation as in a gentle current in a sluice, would be many times magnified by causing the water to fall from a considerable height, constructed an apparatus which was the initiation of hydraulicing. He cut a small ditch in the side of a hill, and built a flume from it to a point 40 ft. above the place where he was working. Here the water entered a common barrel, whose bottom was filled with a cowhide hose 6 in. in diameter, ending in a tin tube 4 ft. long tapering to a 1-in. nozzle. The advantages of the plan were quickly realized, canvas * superseded cowhide, to be replaced in its turn by iron piping, and from the rude attempts of an obscure American miner a new science has grown, termed "hydraulicing" (hydraulicking was the original spelling) in America, and "ground sluicing" in New Zealand.

Advantages.—It has already been shown that, as a general rule, with very few exceptions, the gravels of a lead are very poorly auriferous throughout the upper strata, and that the gold is found almost entirely in a layer of a few in. or a few ft. on the bed-rock. Where the gravels have to be removed by hand for treatment in the sluices and other apparatus, it becomes important to confine the labour to the rich bottom stratum. In hydraulicing, on the other hand, the whole depth of the deposit down to the bed-rock must be taken away, no matter how great the depth may be. This has to be performed by the force of a powerful jet of water, which same water must effect the disintegration of the

* Canvas hose and brass nozzles are still in use in New Zealand in localities where a moderate pressure only is needed.

gravels in the sluices. Consequently the first and greatest *desideratum* is a large and constant supply of water. The supply of water once ensured, the process of the washing is conducted with astonishing economy. Laur,* who was sent to California to report on the gold-mines there to the French Government, estimated that the cost of treating 1 cub. yd. of auriferous gravel by the various methods, would be about as follows :—

	£	s.	d.
With the pan, about	4	0	0
,, rocker, about	1	0	0
,, long-tom, about	0	4	0
,, hydraulic process, about	0	0	2½

These prices are assuming the rate of wages to be about 16*s.* a day. The figure for the hydraulic process includes the cost of water.

Essential conditions.—Before commencing a hydraulic washing, the first thing to be done is to ascertain the total depth of the deposit from the surface to the bed-rock, and to test the richness of the strata throughout, as this will be found to vary from ½*d.* to 4 or 5*s.* per cub. yd. As the whole deposit must be removed and treated, it is essential to study these points with great care, in order to form an estimate of the probable returns, before expending large sums of money. For these purposes, mere boring, though useful as a preliminary guide, is not sufficient. Shafts must be sunk at such points as will indicate the depth and extent of the deposit, the richness of the various strata, and the character of the bottom-rock, in order to be sure that the quantity and quality of the gravel are such as to warrant the undertaking, which will require the expenditure of thousands of pounds without giving any return perhaps for several years. Besides these precautions, accurate topographical surveys must be made, with the view of ascertaining (1) what head or fall of water can be got, and (2) what outlet can be secured for the tailings. These two considerations have equally important bearings upon the success of a hydraulic washing, and, unless they receive proper attention, disappointment and loss are sure to follow. The first point is seldom suffered to escape due attention ; but nothing is more common than to see works stopped, and the expenditure of enormous sums of money rendered fruitless, by a neglect to provide sufficient accommodation for the gigantic masses of earth which are removed. The outlay entailed by a hydraulic mine cannot be justified, except the work be permanent and sufficient gravel be at hand to last for several years' operations, consequently "dump" fall or outlet must be secured for the millions of cubic yards of earth displaced, and it must not be forgotten that, in a loosened condition, it will probably occupy

* Laur's estimate as quoted by the Commissioners for Victoria at the Philadelphia Exhibition is,—Pan, 3*l.* ; rocker, 16*s.* ; long-tom, 4*s.* ; sluice, 1*s.* 6*d.* ; hydraulicing, 3*d.*

twice the space which it filled *in situ*. Numbers of valuable undertakings are suspended through careless inattention to this precaution, and many more would be but for the spring freshets, which help so much to remove the accumulated deposits. Frequently it happens that sufficient fall cannot be obtained from the bed-rock—and of course the drainage must take place from the bed-rock or lowest part of the working—without driving tunnels (it may be several miles in length) under the bed-rock, and even under valleys and through hills, in order to reach a river-valley lying at a level low enough to receive the drainage, and of a capacity adequate to the accommodation of the tailings. The primary cost of opening a hydraulic working, without taking into consideration any expenses for water, will often reach 10,000*l.*, and is sometimes double that amount. It is not too much to say that, other conditions being equal, this sum is risked upon the judgment and care with which the mine has been laid out. The location and inclination of the tunnels and sluices have almost a greater bearing upon the success or failure of a hydraulic mine than has the proportion of gold contained in the gravels, for while 2*d.* worth of gold per cub. yd. has given good returns under favourable conditions, scarcely any amount within the range of what past experience has made known could pay for elementary blunders in the laying out of the workings.

Water supply.—Primarily then, the success of working deep placers is dependent less upon the yield of gold than upon the constancy and amount of the water supply. In America, where hydraulicing is principally developed, this has given rise to a number of so-called Ditch Companies. Originally the corporations of miners collected water solely for use on their own diggings; then they found willing purchasers for any excess they might have beyond their own particular needs; and soon it became evident that to be purveyors of water was more profitable and less risky than to consume it in working gold-diggings. Thus many companies which started as gold companies have in time become ditch companies, and look upon the gold-getting as a secondary consideration. As an illustration of this, mention may be made of a company which expended about 9000*l.* in preliminary operations (before the bed-rock tunnel had been driven), and took out about 10,800*l.* in gold, leaving a profit of 1800*l.* Had it sold the water instead at about 8*d.* per in. per 24 hours, it would have reaped a profit of about 8000*l.*

Division of the subject.—There are thus two distinct phases in hydraulicing:—(1) Collecting and conducting the water to the diggings; (2) applying the water to the extraction of the gold. When the undertaking is of a limited description, these operations may be conveniently combined; but in the Western States of America, the enterprises are generally of such magnitude, and the water-supply question is of such weight, that there is a growing disposition to keep the two branches of the industry distinct, the ditch company selling its water for every purpose to which it may be applied, and the gold company buying its water from the ditch company, and confining its attention to the mining proper. The water is sold generally at prices varying between 5*d.* and 10*d.* (10 to 20c.) per "miners' inch" per diem, the day being variously estimated from 10 to 12 hours.

Miners' "inch."—It may be well here to state what a "miners' inch" is. It is an arbitrary measure of the quantity of water which will flow through a given space in a given time, adopted in the early days of American gold-mining, and established by the law of each miners' camp, without any attempt at a universal scale. Thus there are scarcely two localities where the miners' inch has the same signification, the size and shape of the outlet and the manner of discharging the water varying constantly.

The most common way of estimating the "inch" is the amount of water which will pass through an opening 1 in. square in a plank 2 in. thick, with a pressure of 6 in. above the opening or 7 in. over the centre. The thickness of the plank is sometimes 3 in. The lower front end of the discharge is usually chamfered. Raymond says that with an aperture of 1 sq. in. and a pressure of 6 in., the "inch" will equal 94·7 cub. ft. per hour. In other localities, the pressure used is 10 in., making 109·1 cub. ft. per hour. The average Californian miners' "inch" he puts at 100 cub. ft. per hour, or 1000 cub. ft. per day of 10 hours. He adds the following table of the standard miners' inch :—

Pressure from Surface to Top or Middle of Orifice.	Miners' in.	Cub. Ft. (each 6·23 Gal.)				Authority.
		Per Second.	Per Minute.	Per Hour.	Per 24 Hours.	
in. 6	1	0·039	2.33	140	3,360	Hittell.
,,	1	0·026	1·57	94·7	2,274	Carpenter.
,,	38	1·000	60·00	3600·0	86,400	,,
,,	1000	26⅛	1580	94,700	2,274,000	,,
10	1	0·03	1·8	109·1	2,618	,,
6 to 10	1	0·027	1·6	100	2,400	Standard experimental miners' in.
,,	10	0·27	16	1,000	24,000	
,,	100	2·7	166	10,000	240,000	
,,	1000	27	1666	100,000	2,400,000	

The Milton Co. reckon a flow through an aperture 12 in. wide and 12¾ in. high, when the water stands 6 in. above the top of the opening, as 200 "inches."

Raymond observes that the "usual acceptation of the miners' inch is that given by Hittell," and he quotes the following formula from Haswell for making the calculation :—

$$\tfrac{2}{3} b \sqrt{2g} \, (h' \sqrt{h'} - h \sqrt{h}) \, C = V \, ;$$

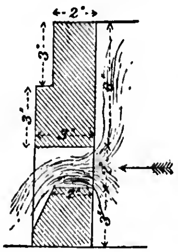
b being the breadth, *h'* the distance from the sill to the surface, and *h* the distance from the top of the opening to the surface in feet, while C is the coefficient of discharge assumed at 0·750, and V the volume in cub. ft. per second; thus—

$$\frac{2}{3} \times \frac{1}{12} \sqrt{2g} \left(\frac{7}{12} \sqrt{\frac{7}{12}} - \frac{6}{12} \sqrt{\frac{6}{12}}\right) \times 0{\cdot}750 = 0{\cdot}031 \text{ nearly.}$$

He thinks the coefficient of discharge is perhaps a little too high.

Egleston states that the "quantity of water which will flow from an opening 1 in. square will be 93 lb. per minute. The opening, however, is never made 1 in. square, but is always longer or higher, which will necessarily increase the quantity of water which will issue from each sq. in. Thus the quantity of water which is given by a single sq. in. opening will be 93 lb. per minute, and from an opening 1 in. × 2 in. will be 196½ lb., and with 1 in. × 100 in. each inch will pass 111 lb. Sometimes the opening is 2 in. high. At North Bloomfield, it is 48 in. long × 2 in. high, with a pressure of 9 in. above the opening. Each square inch will thus furnish 4252 cub. ft. per 24 hours. At Eureka, the opening is the same, 48 in. × 2 in., with 6 in. pressure above the top of the opening, so that each square inch will furnish 3240 cub. ft. per 24 hours. . . . The La Grange inch is equal to 2·159 cub. ft. To determine the value of the North Bloomfield 'inch,' the water was made to discharge through a 3-in. plank. The bottom of the opening was above the bottom of the tank holding the water (Fig. 100), and was chamfered off 1 in. from the outside, so that the outside opening was 4 in. high. The value of this 'inch' is given in" the following table, which "shows, according to Bowie, the variations in some of the 'inches' and their supply:—

FIG. 100.



MINERS' INCH.

Name of Mine.	Height of Opening.	Length of Opening.	Pressure over Centre of Opening.	Quantity discharged by 1 sq. in. per minute.	Quantity discharged in 24 hours.
	in.	in.	in.	cub. ft.	cub. ft.
Smartsville	4*	†	9	1·76	2534·4
Park Mining Co...	..	..	..	1·39	..
North Bloomfield	2	50	7	..	..
Eureka	2	48	7	..	..

* The bottom of the aperture is on a level with the bottom of the box.
† An opening 250 in. long × 4 in. wide will discharge 1000 Smartsville "inches."
The day is usually reckoned as 11 hours.

		H. Smith, 1874. cub. ft.		A. J. Bowie, 1876. cub. ft.
One miners' in. discharges in 1 second	..	0·2624	..	0·2409
,, ,, 1 minute	..	1·5744	..	1·4994
,, ,, 1 hour	..	94·4640	..	89·9640
,, ,, 24 hours	..	2267·1360	..	2159·1460
Ratio of actual to theoretical discharge	..	61·60 per cent.		59·05 per cent."

On the same subject, Raymond remarks in another report the discrepancies among different companies: thus—

	Height of Aperture.	Pressure.	
Eureka Co. ..	2 in. ..	6 in. ..	The amount delivered by them through 20 in. × 2 in. is considered 40 in.
Excelsior ..	.. ..	10 ,, ..	Measured from centre of orifice.
Sears	.. ..	10 ,, ..	Measured from centre of orifice.
Mokelumne ..	.. ..	4 ,, ..	
Campo Seco ..	.. ..	4 ,, ..	
Phœnix	3 in. ..	4 ,, ..	Over the orifice.
Gold Hill ..	2 ,, ..	4 ,, ..	An inch wide.
Another	3 ,, ..	none ..	An inch wide.

"At Smartsville, water is sold with a head of 9 in., with a 14-in. opening 125 in. long, giving 11·8 per cent. for an 'inch' more than is usually given. The quantity discharged through an opening 4 in. deep, with a 9-in. head over the middle of the opening, with the coefficient of discharge = 0·0615 is 106·6 cub. ft. per hour, or 1·7767 cub. ft. per minute. A 'head of water' is 500 in. daily for 10 hours, and is the quantity required for a first-class hydraulic operation."

Egleston gives the theoretical horse-power of the miners' "inch" as follows:—

Heads in feet	100	90	80	70	60	50	40
	30	20	15	10	5	3	1
Inches to horse-power ..	3·25	3·61	4·06	4·64	5·41	6·50	8·12
	10·8	16·2	21·6	32·5	65	108	325

Raymond estimates that "with a moderate ditch delivery of 4000 in., or 5 heads at 800 in., the work done may be 1 cub. chain or 10,000 cub. yd. per day, or in a 10 days' run, an acre 1 chain deep or 100,000 cub. yd. Taking an average of 2000 cub. yd. per day of 10 hours, moved by 300 in. of water, 5 days would move a cub. chain or 10,000 cub. yd.; 800 in. at 100 ft. head working 10 hours = 800 10-ft. cubes of water = 800,000 cub. ft., weighing 24,880 tons, without adding the pressure arising from the head employed. This will move through ordinary sluices, at a grade of 8 to 12 in. per box, 3000 cub. yd. of loosened gravel, or 2000 cub. yd. of ordinary uncemented bank gravel, say an average of 2500 cub. yd., weighing 8300 tons or $\frac{24880}{8347} = \frac{1}{3}$ of the weight of the water employed. Reckoned by 'inches,' the amount of gravel moved = 3 times as many cub. yd. as there are miners' 'inches' used.

"A cub. ft. of water at 62° F. weighs 63·321 lb.; 1000 cub. ft. = 31·160 tons.

Clay	= 120	lb. per cub. ft.	= 4800 per yd.	Sp. gr. = 1·92	(Water 1·00)
Sand, dry ..	= 88·6	,,	=	,, = 1·42	
,, wet ..	= 118	,,	=	,, = 1·90	
Trap rock ..	= 170	,,	= 4500 ,,	,, = 2·72	
Basalt	= 187·3	,,	= 5060 ,,	,, = 3·00	
Quartz	= 165	,,	= 4450 ,,	,, = 2·65	
Shale..	= 162	,,	= 4370 ,,	,, = 2·60	
Slate (clay) ..	= 180	,,	= 4800 ,,	,, = 2·90	
Decomposed shale estimated	= 100	,,	= 2700 ,,	,, = 1·80	

"The breadth, depth, and velocity of a stream in feet per minute as travelled by a chip, may be estimated by the eye. The sectional area being reduced to sq. ft. and decimals, we have multiple × 60 = cub. ft. per hour; divided by 100 = miners' 'inches.' Or, observe 6 seconds, and the distance × area × 6 = miners' 'inches.'

"The miners' 'pan' contains about 400 cub. in. of loose dirt."

The results of some interesting experiments to test the relative carrying powers of one 20-in. sluice and two 10-in. sluices, communicated by F. L. Vinton to the 'Engineering and Mining Journal,' of New York, may be summarized in the following tables:—

First Experiment—Sluice Level.

Area of discharge	0·139 sq. ft.	Actual discharge	0·276 cub. ft.
Velocity	1·985 ft.	Theoretical discharge by formula $Q\ 5 \cdot 6\ a - \frac{H}{\sqrt{H+h}}$	0·269 ,,
Mean depth	0·13 ,,		

Second Experiment—Sluice Level.

Area of discharge	0·347 sq. ft.	Actual discharge	0·702 cub. ft.
Velocity	2·02 ft.	Theoretical discharge	0·716 ,,
Mean depth	0·23 ,,		

First Experiment on Graded Sluices; grade ¼ in. to box of 12 ft. $= \frac{1}{576}$ = 0·0017.

Area of discharge	0·295 sq. ft.	Actual discharge	0·657 cub. ft.
Velocity	2·22 ft.	Theoretical grade by formula $\sin. = \frac{P}{A} V^2 \frac{1}{1000}$	0·0033 ft.
Perimeter	2·02 ,,		
Grade	0·0017 ft.		
Area of discharge	0·147 sq. ft.	Grade	0·0017 ft.
Velocity	1·9 ft.	Actual discharge	0·279 cub. ft.
Perimeter	1·18 ,,	Theoretical grade	0·0028 ,,

Double sluice carries 0·177 more than twice the single on this grade.

Second Experiment on Grade; grade ½ in. to 12 ft. = 0·0035.

Area of discharge	0·295 sq. ft.	Grade	0·0035 ft.
Velocity	2·271 ft.	Actual discharge	0·671 cub. ft.
Perimeter	2·02 ,,	Theoretical grade	0·0035 ,,
Area of discharge	0·147 sq. ft.	Grade	0·0035 ft.
Velocity	2·00 ft.	Actual discharge	0·287 cub. ft.
Perimeter	1·18 ,,	Theoretical grade	0·0032 ,,

Discharge of double sluice is 0·168 more than two single on this grade.

Third Experiment on Grade; grade ¾ in. to 12 ft. = 0·0052.

Area of discharge	0·295 sq. ft.	Grade	0·0052 ft.
Velocity	2·8 ft.	Actual discharge	0·827 cub. ft.
Perimeter	2·02 ,,	Theoretical grade	0·0053 ,,
Area of discharge	0·147 sq. ft.	Grade	0·0052 ft.
Velocity	2·21 ft.	Actual discharge	0·325 cub. ft.
Perimeter	1·18 ,,	Theoretical grade	0·0035 ,,

Discharge of double sluice is 0·272 more than two single on this grade.

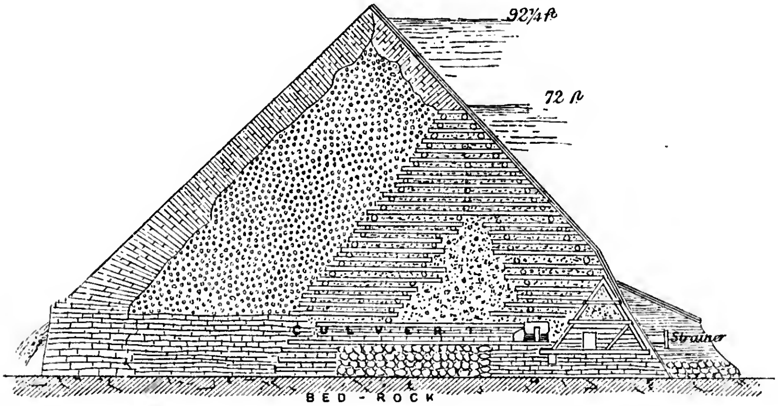
Securing Water Supply.—The greatest engineering skill is required in hydraulicing. In choosing the site and line for a "ditch," the first consideration must be that it shall have a full supply of water all the year round. To secure this object, no outlay should be considered too great. The summer supply is more important than it seems at first sight. The days are then long, and the workmen less exposed to the inclemencies of the weather. The heat of the sun renders the water almost tepid, and on this account the mercury is much more free and energetic in its action, giving a proportionately larger yield of gold. The natural supplies of water vary with the seasons: at one time there may be a heavy flood, at another a long drought; for this reason, dams and reservoirs have to be built, to catch and deliver the water as it may be needed.

Dams and reservoirs.—The object of these constructions is to take in not only the running water supply, but all the water from rains, floods, and snows melting on the hills, and to store it in the spring and summer months for use during the dry season. Dams are usually built where the opening is narrow and rock-walled, the material used varying with the nature of the local supply. Sometimes cut granite blocks are keyed together for the face, the backing being composed of puddled clay and earth. Wooden dams are often made by cutting down the neighbouring trees, running them from shore to shore, 6 to 8 ft. apart for a width of 40 to 50 ft., then placing other trees at right angles to these, about the same distance apart, building up a sort of crib. Where the trees cross, they are fastened together with bolts, and the intervals are filled in with rubble. The trees lying parallel with the stream are usually put in with part of their branches on, and heading up stream. It should, if possible, be arranged for the outlet to be in solid rock.

The following details concerning one of the largest dams in America possess great interest. The dam was first built to a height of 72 ft., as indicated in Fig. 101, consisting of a timber crib of unhewn logs of cedar and tamarack woods, notched and securely bolted together, and filled in with loose rubble. A water-tight lining was formed by spiking pine planking to the water face. Subsequently the height was increased to 96¼ ft. above datum line (100 ft. total height); but at 85 ft., it was thought advisable to let a stream of water, 50 to 75 cub. ft. per second, flow over the summit and percolate through the stone embankment, so as to settle the structure before adding the top courses.

The increased height was effected by filling in a stone embankment on the lower side of the old structure, faced with heavy walls of dry rubble of large size. The lower face wall is 15 to 18 ft. thick at bottom, diminishing to 6 to 8 ft. at top, the stones varying from ¾ to 4½ tons each in weight, with many equally large stones in the backing. The under portion is $17\frac{1}{2}$ ft. high, with a 15 per cent. batter, built of heavy stones in horizontal layers, and the face stone tied to the backing with iron dowels. The upper part of the wall is sloped at 45°, and the face stone is embedded at $22\frac{1}{2}$°, thus dividing the angle between a horizontal bed and a bed at right angles to the face, no attempt at ranging being made in this portion. Above the 68-ft. line, ribs of flattened cedar 8 in. thick are built into the upper face wall, and tied to it by iron rods 5 ft. long × $\frac{3}{4}$ in. diameter, and to these ribs is

FIG. 101.



DAM FOR HYDRAULIC RESERVOIR.

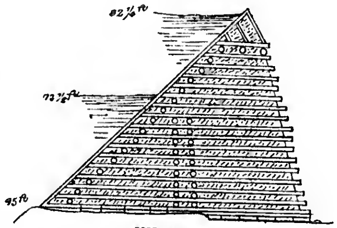
firmly spiked a planking of heart sugar pine 3 in. thick × 8 in. wide, with planed edges fitted with an outgage like ships' planking. The planking was put on almost thoroughly seasoned, and would swell sufficiently to make the face practically water-tight without caulking or battening the joints. The openings at the joints made by the outgage suck in small particles of vegetable matter, which in a great measure take the place of caulking.

At the bottom, the plank is fitted neatly to firm bed-rock, and caulked with pine wedges. There are three thicknesses of plank (total 9 in.) on the lowest 25 ft., two thicknesses (6 in.) on the next 35 ft., and one thickness on the uppermost 36 ft. Experience justifies the belief that this will remain sound for at least 20 years, when it can easily be renewed. The dam is traversed by a culvert, through which the water is drawn from the reservoir. This is built of heavy dry rubble foundation and walls, and covered with granite slabs $6\frac{1}{3}$ ft. long × 16 to 18 in. thick. Three No. 12 wrought-iron pipes, each 18 in. diameter, penetrate the water face of the dam, whose upper mouths are protected by a strainer of 2-in. plank, anchored to the bed-rock. A separate valve or gate is placed at the lower end of each pipe; the water passing through the three gates, amounting to 280 cub. ft. per second, discharges into a covered timber sluice $7\frac{1}{2}$ ft. wide × $1\frac{3}{4}$ ft. high, reaching the lower edge of the dam, and opening on to the solid bed-rock of the creek bed. The gates are reached by a man-way above the sluice.

The crest of the dam will be formed by a coping of hewn heart cedar timbers, 18 in. wide on top, and fastened securely to the stone wall below by means of iron bolts. In building the lower face wall, care has been taken that it shall be able to resist a large stream of water passing over the crest. In such a case, much water would enter the structure, owing to the inclined beds of the face stone and the flat slope of the wall, and would seek escape through the interstices purposely left in the nearly vertical portion of the lower wall. To prevent the consequent hydrostatic pressure, which would accumulate at the base of the dam to perhaps 20 lb. per sq. in., from forcing out the lower face of the wall, the careful building and tying with iron rods was adopted. The dam is built V-shaped, with the vertex of the angle of 15° pointing upstream. The flat slope of 45° was adopted for the walls, as the supply of material was abundant, and it allowed much lighter face-walls to be used.

In connection with the main dam is a waste dam (Fig. 102), which consists of a series of cribs of round cedar timbers, 12 to 30 in. diameter, notched down to heart wood at the joints, and firmly bolted with $\frac{3}{4}$-in. and 1-in. long drift bolts, the foundation logs being fastened to the bed-rock with $1\frac{1}{2}$-in. iron dowels. The cribs are solidly filled up with granite rubble of all sizes, from several tons to a few lb., no sand or fine stuff being used. The water-tight lining resembles that on the main dam, being a plank facing of 3-in. heart sugar pine. The crest of the dam is $92\frac{1}{4}$ ft. above datum line; in it are cut 28 waste-ways, each 4 ft. wide, and 7 ft. deep below the crest. When all danger from freshets has passed, they are closed with boards 2 in. thick × 8 in. wide × $4\frac{1}{2}$ ft. long, placed horizontally, and sliding to their seats one above the other on the incline of the water face. This style of gate is the simplest known, and has been proved by long experience to be the best. The structure is believed to be sufficiently strong to allow a flood of 16,000 cub. ft. of water per second to pass through the wastes and over the crest, without causing damage.

FIG. 102.



WASTE DAM.

Ditches.—The two great points to be borne in mind when laying out a " ditch," are that it shall have a full supply of water all the year round, and that it shall have the greatest possible elevation where it reaches the point at which the water is to be used, the object being not only to supply the diggings in immediate contemplation with water at high pressure, but to be prepared to take advantage of other diggings which may be opened

FIG. 103. FIG. 105.

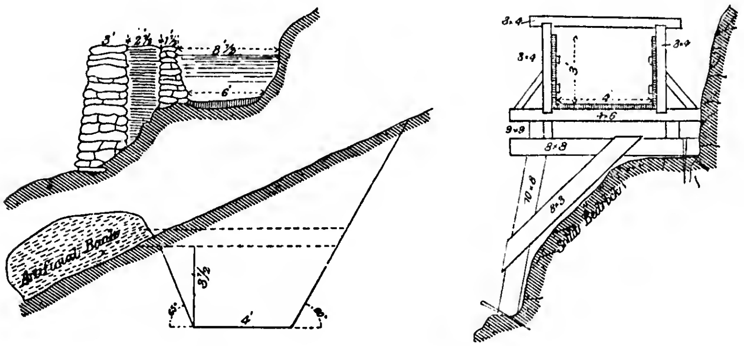


FIG. 104.

DITCHES AND FLUMES.

later. The selection of the route to be followed by the ditch is a matter calling forth the greatest skill and judgment of the engineer. By neglect in the first construction, an amount of repairs may be necessitated that in a few years may exceed the original cost of the ditch ; in fact, it is almost impossible to remedy primary defects, and economy in the first instance is always the most expensive in the long run.

An effort should be made to keep the ditch as far as possible between earthen banks, and it must not be forgotten that, until the stream itself has filled the pores of the ground through which it passes, it is sure to give much trouble. The greatest care must be taken to select ground which is solid, and to avoid such as is likely to produce slides. Often it happens that the nature of the ground will not permit the outside bank to be of earth, in which case masonry may best be substituted, as shown in Fig. 103, or the ditch may be temporarily suspended, and a wooden flume (Fig. 105) run in its stead. In fact, a variety of means may have to be adopted in order to secure the desired line ; it may be necessary to cut a tunnel through a hill, or to employ iron piping in order to cross a valley. The ditch should not be built on very steep inclines, and should, if possible, be put so far into the hillside as to have a sufficiently strong bank for its protection outside. The snow-line should at all times be avoided, if possible, as well as those spots where the snow is likely to drift heavily. Where such are unavoidable, provision must be made for the protection of the ditch, by means of snow-sheds or other suitable covering.

Fig. 104 shows the ordinary mode of constructing a ditch. It is graded in from slope-pegs from 6 to 36 in. All trees within 15 to 25 ft. of the edge of the upper bank are rooted up; also the logs, brush, and leaves from the lower bank, under the artificial bank, are carefully removed.

Fig. 105 shows the method of posting along cliffs, where the foundation is occasionally narrower than the flume. Where flumes connect with the ditch, the posts of the flumes for a distance of several boxes are 4 and 4½ ft. high, allowing an additional side plank. The planking is 2 in. thick.

It is generally preferable to make the ditch deep rather than wide, on account of evaporation. A swift current through a narrow ditch can be made to deliver as much water as a slow current through a wide one, and has the advantage of keeping the ditch free from snow, ice, fallen leaves, and other encumbrances liable to clog it at various seasons. But it is not always possible to observe this rule, for it may happen that, by coming too near the bed-rock, there will be greater leakage than evaporation, so that the reverse plan must be adopted. Great sources of leakage are the holes left by decayed roots, and the filtration of the water beside the roots left in the ground. This is especially the case when the trees found on the line of the ditch are cut down, as is so commonly done, and may be in a great measure remedied by undermining the trees, cutting off the small roots, and rolling the tree, roots and all, down the hillside.

During the summer, the supply of water is often reduced to one-third of its normal amount, a result due to increased leakage and evaporation, as well as diminished rainfall. To overcome the evil as much as possible, all the streams met with on the line of the ditch are made to flow into it as tributaries; but where torrents are encountered, the ditch should be taken over them at a sufficient height to escape the greatest freshets that occur.

As the stream and reservoir supplies combined will probably furnish an excess of water during the wet season, flood-gates must be provided at suitable distances, so as to relieve the pressure, which might endanger the ditch. They also admit of the ditch being rapidly repaired, as the water may be turned out of any section, as required. Overflows must also be constructed, so that a slight flush of water may not injure the banks. All these water outlets must be so arranged and protected as to avoid the possibility of the water undermining the banks of the ditch. The ditch is generally built in sections, which must be connected as rapidly as possible, to be used for the transportation of material. In process of time, the banks of the ditches settle, and become covered in many instances by a permanent growth of grass and bushes, so that a serious break, even during the severest storms, is very improbable. As to the grade of the ditch, Egleston recommends that 10 ft. per mile should be adopted, as having been proved by Californian experience to be the best on the whole, and one which, while giving the proper velocity, will least endanger the banks. Ditches having a grade of 15 to 20 ft. per mile, delivering 80 cub. ft. per second, have been successfully used; but they are exceptional. The grade, once determined, must or should be adhered to throughout.

The following table will illustrate the degree to which ditches differ in their proportions:—

Name.	Length of Ditch.	Width of Top of Ditch.	Width of Bottom of Ditch.	Depth of Ditch.	Cost of Ditch.	Average Grade per Mile.	Discharge in Miners' Inches.
	miles	ft.	ft.	ft.	£		
Milton	100	6	4	3·5	52,000	14·5	3000
North Bloomfield	55	8·65	5	3·5	84,000	14	3200
.. .. .. (1.)	60	8	6	4	..	..	2200
Spring Valley .. .. (2.)	52	6	4	3·5	..	..	2000
Hendrick's	46·5	6	4	2	27,000	9·6	..
San Juan	45	..	..	..	59,000	..	1300
South Yuba .. .. (3.)	35	8	4	4	..	..	..
Excelsior	33	8	5	4	..	9	1700
La Grange .. .. (4.)	20	9	6	4	90,000	7·5	3000
Eureka Lake	18	..	..	..	86,000	..	2800
Union	15	8	4	3·5	..	13	1200
Boyer	15	8	4	3·5	..	13	1200
.. .. .. (5.)	..	6·5	4	3	..	11·2	3000
.. .. .. (6.)	..	..	3	3	..	..	2000

1. On the line of the ditch are 4 miles of iron pipe, 30-in. diameter, one section of which conducts the water across a branch of a river. It is laid as an inverted syphon, and has a vertical depression of 856 ft. The receiving arm has a head of 180 ft. vertical pressure; length of syphon, 2½ miles.

2. This has 3½ miles of 30-in. iron pipe.

3. With a subsidiary ditch, grade 10 ft. per mile, current 2½ ft. deep. It is carried across a narrow cañon by a wire suspension flume, and across another by a truss flume with a span of 60 ft.

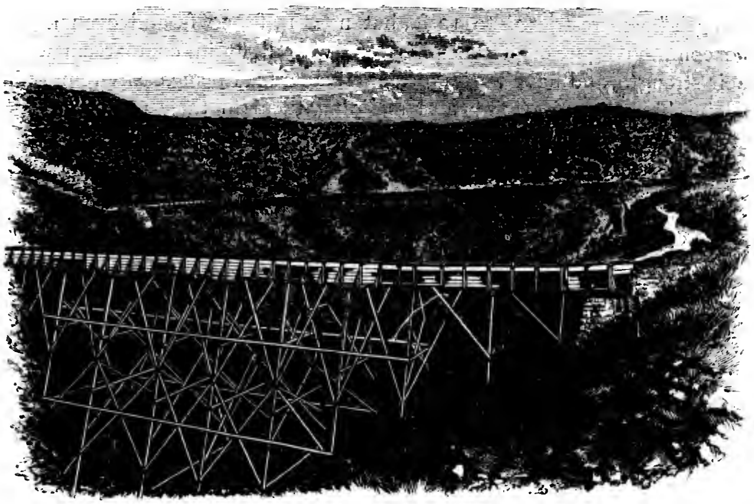
4. Most of this ditch is hewn in granite.

5. The line is graded 7½ ft. wide, and excavation made close into the bank, leaving not less than 1 ft. of solid earth on the outside.

6. To cross a creek the water is led into a 27-in. pipe, 420 ft. long, and with a depression and elevation of 75 ft.

Flumes.—It sometimes happens that the ditch must cross ravines of some depth, or be carried over a long stretch of level ground, in order to deliver the water at the proper height. In such cases, wooden flumes or launders are often used to conduct the water. Their employment should be avoided on all possible occasions, as they are very expensive to build, need constant repair, are very liable to burn down in summer, and in winter are very likely to freeze solid, especially where they are exposed to all winds. Formerly they were much more favoured than now, because wood was plentiful and cheap, iron dear and difficult of transport; but no engineer nowadays would think of copying such gigantic and expensive structures as that built near Smartsville, and which has served to adorn numberless pages. Nevertheless, smaller constructions of the kind are a common feature in the mining districts, despite their objections. They are generally made smaller than the ditch, and therefore of much higher grade, in order to accommodate the same quantity of water. A common grade is 30 to 35 ft. per mile, and they should be set in as straight lines as possible; if a curve must be made, it should be of very wide radius. The utmost attention should be paid to the foundations, and to placing the uprights so that they shall not settle, as nothing is so detrimental to a proper water-supply as a change of grade in the flumes through settling. Where the grade changes, the water is almost sure to freeze solid, and thousands of feet have sometimes to be cut out for that reason. The posts should be placed above the ground, so as not to rot; the planking is 12 in. to 18 in. wide and $1\frac{1}{2}$ to 2 in. thick. The joints are covered on the outside by st[illegible] in. wide and $1\frac{1}{2}$ in. thick. The flume is supported at every 4 ft.

Fig. 106.



Scandinavian Water-race, New Zealand.

by a framing of 4 in. × 4 in. timber; the sills in the heavy flumes extend 18 in., and are braced to the side, the lighter ones are braced to the uprights. An example erected in New Zealand is shown in Fig. 106.

When very high, flumes should be anchored with wire rope, as a safeguard against swaying with the wind. They should be built in an open country, if possible, as a protection against forest fires; and brushwood and other inflammable material should be removed from their vicinity. When it is impossible to put them in open country, they should be carried as close as possible to the bank, so that, in the event of snow-slides, &c., the snow may pass over, and not against them. Under the best conditions, free from ordinary accidents, flumes will not last longer than 10 to 15 years. This is emphatically the case where they run dry during a portion of the year, for it is a well-known fact that wood which is sometimes wet and sometimes dry will last a much shorter time than that which is always wet or always dry. The alternate expansions and contractions destroy the fibre of the wood, and start the nails and wedges. The average cost of repairs to a flume will almost double that of an equal length of ditch. On this account, attempts have been made to replace the wooden flume by one of sheet iron, but the policy is doubtfully wise, and does not seem to have had many adherents.

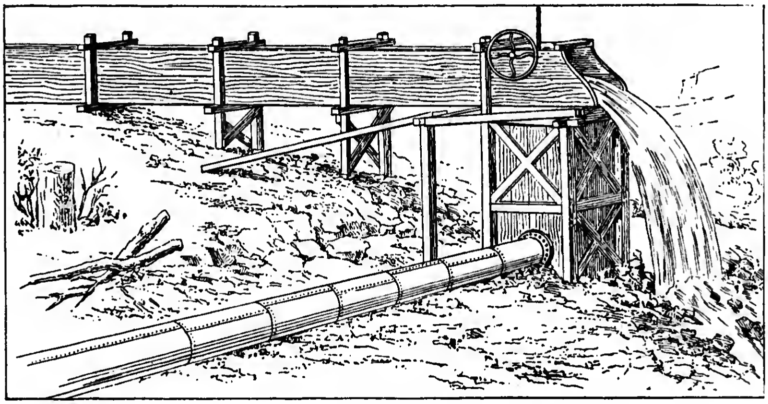
Pipes.—There is no doubt that wherever it is possible to do so, wooden flumes may best be supplanted by iron pipes. These are generally made of No. 12 to No. 16 sheet iron, in variable lengths, which are joined together when placed in position on the ground. At first the "length" was restricted to 12 ft., but now 15 ft., 20 ft. and even more are common figures. These pipes are very light in comparison with their strength, and have the important advantage of being easily removed, by simply cutting the joints and rejoining them in their new position. Repairs are facilitated by the same reason, and a few extra lengths are always kept on hand so as to avoid delays. The pipes are best buried in the earth, at a sufficient depth to escape the expanding and contracting effects of the weather; when above ground, they are borne on trestles. Sometimes it is inconvenient to carry a flume across a place, or to run the pipe as a siphon, in which case the pipe may be led across on frames, built like a flume, with only a floor and a top board. The pipes are generally riveted together, and will stand very great pressure, more frequently collapsing than bursting.

The Spring Valley Water Co. has 17 miles of 30-in. riveted wrought-iron pipe, which carries water across depressions of 150 ft., 200 ft., and 250 ft. in vertical height; and 14,000 ft. of 30-in. pipe was laid across a valley nearly 1000 ft. deep. In such a case, the water must be discharged into a head-box at a point high enough above the discharge-level to give pressure sufficient to overcome the friction, which in this instance was estimated at 20 ft.

Raymond mentions 2 miles of pipe made of sheet iron, in 20-ft. sections, slipping one into another, and tapering from the reservoir to the workings from 22 in. to 8 in. In another case, the joints were fastened together by a riveted sheet-iron collar, made of No. 16 iron, 3 in. wide, daubed over with melted asphaltum, slipped over the joints and held in place by the adhesion of the asphaltum. As originally constructed, a portion of the pipe was intended to withstand a pressure of 650 ft. in crossing a sag in the mountain; but when the water was turned on, the pressure forced it all out of the joints. Leading the joints was next tried, but with no better success; and as the efficacy of an inside collar, as usually applied in such cases, was not known, the pipe had to be taken up and run round the mountain.

The same authority gives some details of the construction of another pipe, which cannot fail to be interesting. The inlet to the pipe was 150 ft. above the outlet, with a vertical height of 900 ft. from the lowest point to grade line. The pipe was 30 in. diameter, and intended to carry 1900 miners' "inches" of water. The thickness of iron used was No. 14 for 150-ft. pressure, No. 12 for 275-ft., No. 10 for 350-ft., No. 7 for 425-ft., $\frac{1}{4}$ in. for 600-ft., $\frac{5}{16}$ in. for 850-ft., and $\frac{3}{8}$ in. for 900-ft. The water was admitted at the upper end from a cistern with sand-box, &c., for settling any sand or gravel brought in from the ditch. Here the pipe had an elbow dipping into the water, to prevent the entrance of air, and at 50 ft. from the inlet there was a standpipe to permit the

FIG. 107.



HEAD-BOX.

escape of any air accidentally imprisoned. The pipe was laid in a trench 5 ft. deep, and covered with earth to prevent undue expansion and contraction in hot and cold weather. The sections were 23 ft. long, and were riveted one to another continuously, manholes being placed at every 1000 ft. to allow of the entrance of the workmen. The rivets used were, for No. 14 iron, $\frac{1}{4}$-in. wire; No. 12, $\frac{1}{4}$-in.; No. 11, $\frac{5}{16}$-in.; No. 9, $\frac{3}{8}$-in.; and No. 7, $\frac{3}{8}$-in., driven cold. The $\frac{1}{4}$-in. iron was machine-riveted cold, hand-riveted hot; $\frac{5}{16}$, $\frac{5}{8}$, $\frac{3}{8}$, $\frac{3}{4}$ driven hot. A steam riveting-machine was principally used, and found much superior to hand. The $\frac{3}{8}$-in. *wrought* iron here sustains a pressure of 385 lb. per sq. in., which would require nearly 3-in. *cast* iron.

The supply-pipes discharge into a head-box, such as is shown in Fig. 107. This box, which is made of great strength, is usually about

8 ft. deep, and is provided with an iron grating, to keep out floating matters. The greater the depth of water in the bulkhead over the mouth of the pipe, the less air can enter it. There should never be less than 4 ft., and 5 or 6 ft. is much better.

The feed-piping is made sometimes of canvas, sometimes of iron: canvas hose is only used in inaccessible places, or on very small claims, and is made of heavy duck sewn together. With ordinary sewing, it will bear a pressure of 50 ft. perpendicular without other support. When greater pressure is needed, it is surrounded by iron rings, about 3 in. apart, and connected by cords, then called "crinoline" hose, and equal to a pressure of 180 ft. of water. Failing iron rings, a netting of $\frac{1}{4}$-in. or $\frac{1}{2}$-in. rope, with meshes about 2 in. sq., may be used, and is almost equally strong. Pipe of this description can be easily shortened, lengthened, repaired, and transported, and seemed, at the time of its invention, to be the perfection of a water-conduit; but it was not long before iron piping generally supplanted it.

The ordinary dimensions of iron feed-pipes are as follow:—

Diameter of Pipe.	Pressure.	Number of Iron.	Thickness of Iron in Decimals of an inch.
in.	ft.		
22	150	16	0·060
22	150 to 250	14	0·078
22	250 to 310	12	0·098
30	150	14	0·078
30	150 to 275	12	0·098
40	160	..	0·236

The iron used varies generally from No. 16 to No. 11, according to the pressure, the best iron only being employed. The size of the pipe will depend upon the supply of water; with 1500 to 2000 in. of water, a 22-in. pipe will suffice; where the supply is 3000 in., a 30-in. pipe must be used, and so on.

The feed-pipe should pass from the bulkhead to the workings in as direct a line as possible, and upon an even grade, and should be furnished with air-valves about 2 in. in diameter at about every 100 ft. of its length. These valves are of paramount importance, for in case there should be any depression in the pipe, the water would be retained there, and if it should be discharged faster than it can enter the pipe, a collapse must take place, unless the valves are in their places and working to prevent the formation of a vacuum. They should be of brass, and never of wood, for the latter have been known to swell, and become so tight as not to act, resulting in a collapse of the pipe, against which every precaution should be taken, as the least inconvenience it can occasion will be a serious delay.

The feed-pipe terminates in a distributor, generally a cast-iron box provided with openings, to which are attached the pipes carrying the nozzles. These openings are closed by ordinary water-gates, which are worked through a screw on the outside, by which the water is supplied to or shut off from any one of the nozzles. The distributors have as many as 4 gates when the water-supply is adequate for 4 nozzles from a single box. When the site for the distributor has been chosen, it is permanently fixed there. The pipes leading from the distributor to the nozzles are 10 in. to 15 in. in diameter, made of No. 14 to No. 12 sheet iron in 12-ft. lengths, composed of sections, 18 in. long, riveted together. The lengths, or "boxes," as they are also called, in imitation of the 12-ft. lengths of the sluices, are occasionally connected by flanges, or by hooks and wire, and in some cases are simply telescoped together like stove-piping. Another plan is to use bolts and nuts, so that the structure may be easily set up or taken apart. In all cases, the joints must be made quite tight. The pipe is generally supported so as to avoid bends; if laid on the ground, great attention must be paid to the air-valves, and each "box" should be well painted with coal-tar. The miners always repair their own pipes, a workshop and appliances being maintained for the purpose.

Nozzles.—Passing mention has already been made of "nozzles." Their use is to concentrate the water so that it shall be discharged against the bank with sufficient force. Several kinds of nozzle have been introduced from time to time, one of the first being that shown in Fig. 108, and known as a "goose-neck." It consists of two elbows of iron pipe *a*, working one over another, with a flexible joint *b* between them, which admits of a certain amount of rotation in a horizontal plane; while the piece of hose *c*, inserted between the upper elbow and the nozzle *d*, permits a moderate vertical movement. The facility of moving in all directions constitutes a great improvement on the straight nozzle; but the sharp double bend of the elbow reduces the force of the water, and the flexible joint is liable to get hard and "buck."

Craig's "monitor," Fig. 109, was devised to remedy these defects. Its principal parts are: a hollow globe *a* provided with two openings, one at the side for admitting the main supply-pipe, and a second on the top for feeding the nozzle. The latter has an elbow with a hemispherical attachment *b*, turned so as to exactly fit the inside of the flange *c*, which is bolted to the globe, and, with the leather packing, makes a water-tight joint. The nozzle is thus movable in any direction at will, to the extent of nearly 40° vertically and 360° horizontally. The apparatus is bolted firmly to the timber structure *d*. The nozzle is composed of a wrought-iron tube *e*, 10 ft. long, to the end of which is screwed the nozzle proper, made of cast iron, and 6 to 8 in. inside diameter. When the direction has been determined, the nozzle is commonly tied in place; but with 180-ft. pressure, it needs no support.

Fisher's "knuckle-joint," Fig. 110, consists of two elbows *g*, placed together in the form of an S, and arranged to rotate horizontally by means of a ring-joint *a* furnished with friction-rollers. The ring is slipped down over the lower elbow, and held in place by a flange on the pipe; then bolted to a flange on the top elbow, joining the two, but

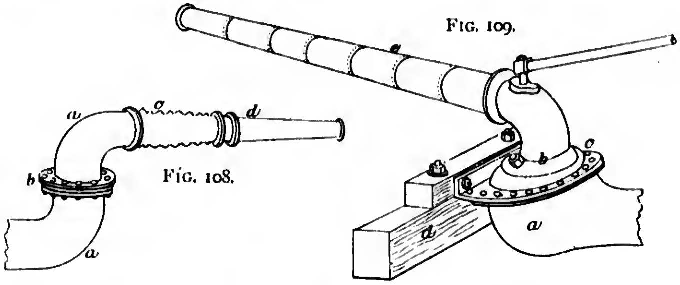


FIG. 108.

FIG. 109.

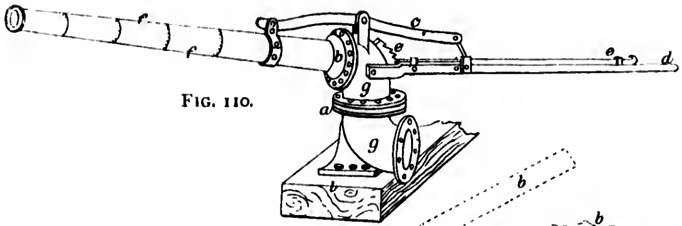


FIG. 110.

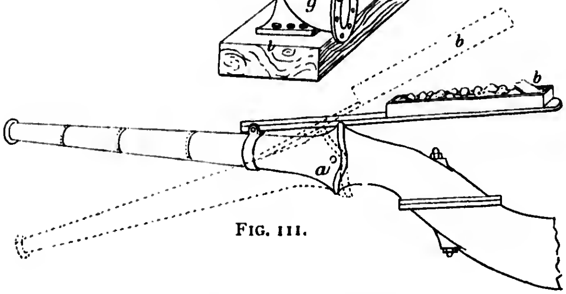


FIG. 111.

HYDRAULIC HOSE NOZZLES.

allowing the latter free action. Indiarubber is used to make the joints water-tight. The nozzle is secured to the upper elbow by means of a knuckle-joint *b*. Movement in all directions is easy, and can be instantaneously effected, vertically by a series of levers *c d*, the main arm of which is 10 to 12 ft. long, and held in place by a ratchet *e*. The elbow and knuckle-joint are of cast iron, $\frac{5}{8}$ in. to $\frac{3}{4}$ in. thick; the pipe *f* is of No. 16 sheet iron, 8 ft. long, the nozzle of cast iron. The pipe does good work to a range of 200 ft., and keeps its position when in use.

Two forms of nozzle have been invented by Hoskins, and both are extensively employed. The earlier form was the "dictator," which differed from Craig's monitor principally in that the joint was external instead of internal, causing the water to have a tendency to force the joints apart rather than together. Indiarubber packing is used in the joint, and friction wheels are introduced to reduce the friction, so that the pressure being all against elastic packing, the nozzle is easily managed, and its movements are easy. It has the same motions as Craig's, but its construction is more complicated, and the sharp bends of the joint cause a loss of power. The later and most popular form is the "little giant," shown in Fig. 111. It is very simple, easily repaired, has no sharp curves, and is said to discharge the greatest amount of water with the least resistance. Horizontally it rotates completely, and moves vertically on the knuckle-joint *a*, which is kept in place by a counterpoise at *b*. Leather is used for packing the joints water-tight, and the inside of the nozzle is fitted with three rifle-plates, which force the water to issue in a straight line, and prevent its acquiring that rotary motion which is so common when the velocity is high, and which causes the stream to break up and lose much of its effectiveness. A 6-in. "little giant" nozzle has been worked with a pressure of 435 ft.

The discharge of water through these nozzles will be 1000 to 1500 cub. ft. per second, according to the pressure and to the size of the nozzle, the velocity reaching 150 ft. per second, and being such as can be compared only with the force of artillery. The size of the nozzle and the pressure of the water must be regulated in each case according to the circumstances, the amount of water required varying greatly with the situation and character of the bank, and the size and grade of the sluices. The supply can be regulated from the distributor. It will generally be found best to arrange for a maximum supply and pressure; in low-grade sluices, as much as 1½ cub. yd. per miners' "inch" may be washed, while in high-grade sluices, it may reach 5 cub. yd. With a fall of ½ in. per ft., 7 cub. ft. of water will be needed to work 1 cub. ft. of gravel.

Tunnels and shafts.—The next point to be considered is the location and construction of the tunnel and shafts through which the gold-bearing gravels have to be washed. The line of the tunnel will have been chosen during the preliminary survey of the ground, and with the object of meeting the following requirements:—(1) It must be perfectly straight, so as to be as short and simple as possible; (2) it should be driven so as to reach the lowest possible point of the bed-rock that is to be worked; (3) it should be taken as near as possible to the centre of the basin containing the gravels, before any attempt is made to connect it with the surface; (4) it must be provided with efficient ventilation; and (5) the grade, generally 4 to 7 per cent., must be consistent throughout, and it is better to have too steep a grade than too low, because the former may be remedied while the latter cannot.

The tunnel forms the outlet of the workings, and in it (as well as beyond it) are placed the sluice-boxes for catching the gold. The dimensions of the tunnel will therefore depend on those of the sluices, allowing about 2 to 2½ ft. of extra room; and the size of the sluices will vary in proportion to the quantity of material and water to be passed through them, and the duration of the mining season. For single sluices about 6 ft. square, running 8 or 9 months in the year, a tunnel 8 ft. high and 7 ft. wide is commonly made, which at 4 per cent. grade will consume 2000 to 2500 miners' "inches" of water. For a consumption of 3000 to 3500 miners' "inches" of water, larger tunnels and double sets of sluices are preferable. The grade should be as high as can safely be used, both for the purpose of breaking up the material thoroughly, and to ensure against choking, at the same time that it must not be so steep as to create undue wear and tear of the sluices; it will vary, in inverse proportion to the size of the sluice, from 4 to 7 per cent., commonly the former, and with very light and friable dirt even 3½ per cent. may suffice. In length, tunnels vary according to circumstances from hundreds to thousands of feet; and the depth between their outlet and where they abut on the shaft bottom should be 50 to 70 ft., it being seldom easy to get more. For ventilation, an air-shaft or air-boxes must be provided, and when the tunnel is of great length, it would be good policy to have both.

When the tunnel has been run as far as possible towards the centre of the basin, a shaft may be opened in connection with it; but care should always be taken to avoid opening on the edge of the basin, or near the rim-rock, on account of the likelihood of meeting with quicksands and poor ground, and because, while the expenses and difficulties will be nearly the same in both cases, ground opened in the middle of the deposit will last for a long time, whereas that on the edge will be quickly exhausted. Considerable judgment is required in making this connection. The first precaution necessary is to run a drill down, in order to test the ground and gain an idea of its character. If hard, no difficulty need be apprehended; but if soft, and still worse, if quicksandy, the greatest caution must be observed in conducting the workings, and it may even be wise to abandon the proposed shaft, and seek a new place for an opening. It is preferable, where possible, to make the connection by means of a vertical shaft; but where the ground is soft, it is sometimes necessary to drive the bottom portion of the shaft on an incline; and when very wet, the end of the slope must be protected, and provision made for the water to drain off without disturbing the solid materials. When the shaft drains itself, there will be little trouble in getting through sand or gravel; but failing this, pumping may have to be resorted to, or a drainage-outlet to the tunnel may be made by putting down a bore-hole. Permanence and security must be sought in the construction of the shaft, and it must therefore be heavily and strongly timbered, and lined inside in such a way as to protect the timbers, more especially at the bottom, where very stout material must be used.

The following table will give some idea of the scale of the undertaking:—

Name.	Length of Tunnel.	Average Grade of Tunnel.		Cost (reported).
		In. per Sluice-box.	Ft. per 100.	
	ft.			£
North Bloomfield ..	8000	6½ in. per 12 ft.	4½	100,000
American	7900	10½ ,, ,, 14 ,,	6¼	28,000
French Corral ..	3500	8 ,, ,, 14 ,,	4⅔	33,000
Bedrock	2600	9 ,, ,, 14 ,,	5¼	..
Farrell	2200	6 ,, ,, 14 ,,	3½	..
Sweetland Creek ..	2200	8 ,, ,, 14 ,,	4⅔	18,000
Manzanita	1740	7 ,, ,, 14 ,,	4⅙	12,000
Boston	1600	10½ ,, ,, 12 ,,	7¼	8,000
English mine	1400	12 ,, ,, 14 ,,	7	..

When once the connection between the tunnel and the shaft is established, such modifications as appear advisable may be readily accomplished. An incline may be turned into a shaft, or a shaft into a series of terraces. The latter are considered by some engineers to be more effective in breaking up cement and firm gravel than a single deep drop; when used, they should be arranged so that the fall decreases as they descend:—thus, with 100 ft. fall, the first may be 30 ft., the second 25 ft., the third 20 ft., the fourth 15 ft., the fifth 7½ ft., and the last, into the sluice, 2½ ft. It now and again happens that the lay of the ground and the thickness of the deposit (say 200 to 300 ft. in the centre) may render it possible to commence operations without the aid of a tunnel, by arranging ditches so that the gravel is being worked and returns made while the driving of the tunnel is proceeding. The shaft should always have a safe, water-tight, and well-ventilated compartment, by which the workmen can ascend and descend, for the tunnel must not terminate at the bottom of the shaft, but be prosecuted through to the farther rim-rock, connection between the inner and outer portions of the tunnel being suspended meantime.

Sluices, drops, grizzlies, under-currents, &c.—The tunnel completed and connected with the shaft, the next object of attention will be the sluices. Already much has been said in preceding chapters, pp. 868–9, 879–81, concerning sluices; but though the principle of their construction and function remains the same in all cases, the sluices for hydraulicing require to be of a character in proportion to the increased work expected of them. The sluice-boxes are laid throughout and beyond the tunnel to the point where the tailings are to be deposited or "dumped." The chief objects of attention in laying them out are their grade, and to make them at once permanently strong yet easily movable.

The first set of sluice-boxes will be placed in the tunnel, being either single or double, according to the capacity of the tunnel, and arranged in such a way as to take the largest possible quantity of gravel. When it is intended to wash very large quantities of gravel, the sluices are made double, resting on the same sleepers, and parted by water-gates so placed that the two sections may be worked simultaneously, or the full stream be turned into one partition to the exclusion of the other. These gates are useful also in allowing one part of the sluice to be cleaned up while the other is working, and they greatly facilitate repairs for the same reason. Windlasses and ropes are required to move them when the sluice is full of water. The sluice is sometimes made double only in that section where repairs are anticipated.

The sluices outside the tunnel will vary in length, according to the nature of the dirt being washed, and must be determined in each instance by actual experiment, an increase being necessary if assays of the tailings show a loss of gold. The sluice is generally run on a wide curve, the outside edge being raised ½ to 1 in. to equalize the wear and tear, because in a straight sluice the velocity of the current would be likely to carry away much of the dirt without disintegrating it. The dimensions of the sluice are determined by the quantity of material to be treated, which is governed by the water supply. One 6 ft. wide × 3 ft. deep, with a 4 to 5 per cent. grade, will take about 3500 miners' "inches;" one 4 ft. wide × 2½ ft. deep, with 2½ per cent. grade, 1200 to 1500; or with 4 per cent. grade, 2000 miners' "inches." The water must be in sufficient depth to cover the largest boulder likely to be encountered, so that the body required will vary with the coarseness or fineness of the dirt. With too much water, the riffles are likely to pack, and the yield of gold will be less, increasing with low grade and small body of water. If water is plentiful and cheap, it will to a certain extent atone for low grade; but with water scarce and dear, a high grade is essential. Generally speaking, ordinary gravel needs 4 per cent. and coarse gravel 6 to 7 per cent., the heavier the gravel the steeper the grade and the more water necessary; 4 per cent. is very commonly used, increased to 6 and even 8 for clay, and reduced sometimes to 1½ per cent. for very light dirt.

Water consumed.—At the "No. 8" mine of the North Bloomfield Gravel-Mining Co., during the time from Jan. 1, 1875, to Oct. 3, 1877, 7,071,630 cub. yd. of gravel were washed, with an expenditure of 3,750,797,560 cub. ft. of water. This gives an average of 534 cub. ft. of water required to wash 1 cub. yd. of gravel; or, in other words, the gravel at this locality required for moving it an expenditure of water nearly equal to 20 times its bulk. At the Blue Tent Co.'s mine, where careful record has been kept of the amount of gravel washed, water used, &c., for the past few years, the various kinds of gravel met with were moved at the rate of from 2·38 to 10·12 cub. yd. per miners' "24-hour inch" (which is considered on the San Juan Divide equal to 2230 cub. ft. of water; in the Bear River mines, about 2200), or, in other words, the gravel required, according to its condition, from 8 to 34 times its volume of water to disintegrate it and carry it into the sluices. That which demanded the largest quantity of water specified is described as being "hard, indurated, and clayey."

Hague adopted 7 cub. yd. as the amount of gravel which, on the average, in the divide between the South and the Middle Yuba, could be moved by a "24-hour inch" of water, and this is said by Professor Pettee to be corroborated by the results obtained at Smartsville; 7 cub. yd. to the "24-hour inch" gives an amount of gravel not quite $\frac{1}{12}$ of the volume of the water used. Ashburner considered that a "24-hour inch" of water would move only about 3½ cub. yd. of the lower portion of the gravel deposit in Bear river and its tributaries. This gravel may be considered as representing the hardest kind ordinarily worked by the hydraulic method.

It appears, therefore, that a "24-hour inch" of water will disintegrate and carry into the sluices 2 to 10 cub. yd. of gravel, according to the character of the material. This, with the data previously given, will give an idea of the amount of water required in hydraulicing operations.

When suspending washing operations, it will still be advisable to keep a stream of water flowing through the sluice, to prevent the joints opening, and a consequent loss of mercury and amalgam on resuming work.

Erecting sluice.—After laying out the line and grade of the sluice outside the tunnel, sills measuring 4 in. × 6 in. at least, and 15 ft. long for a double sluice, are placed on the ground 4 ft. apart. Posts 4 to 6 in. sq. and 3 to 3½ ft. long are then fixed, and braced together with 1½-in. planks; a single 8-in. plank is run from sill to sill on each side to serve as a footboard, and facilitate and strengthen the construction. The bottom and sides are of 1½-in. planking, battens being nailed outside over the joints to close the interstices. Next, the lining and paving are introduced.

Paving.—The paving is of various descriptions. In Fig. 112 are seen two sections of a sluice paved with stones. These are oval, placed edgewise, and set with a slant in the direction of the current, their thickness being usually 9 to 12 in. No stones should be used of less than 20 lb. in weight, or the power of the water will displace them. When quarried rock is used, it is laid in the box with a thickness of 15 to 18 in. One man can lay in a day 8 boxes 12 ft. long, with stone 15 in. deep, the width of the box being not less than 3 ft. nor more than 4 ft. The paving is done in compartments, each 6 to 8 ft. long, and held in place by pieces of stout planking fixed across the sluice. This precaution prevents the pavement getting loose, and facilitates repairs when needed. The larger spaces between the stones are filled by running through waste gravel, while the smaller interstices on the top serve the purpose of riffles. Paving of this kind will weigh about 8 tons per every 10 ft. of a double sluice, necessitating a strong structure. A side lining *a*, of 2-in. plank or worn wooden blocks, is nailed on the inside of the sluice, projecting about 2 in. below the surface of the stones, and rising about 10 to 15 in. up the sides; the wear on this is partly saved by an additional lining *b*, 6 to 8 in. wide; *c* is the boarding of the sluice itself; *d*, the footboard on either side. A run with a rock bottom may last for 100 to 150 days.

FIG. 113.

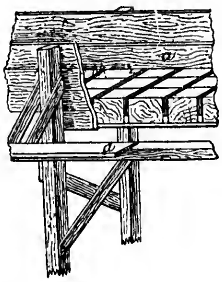
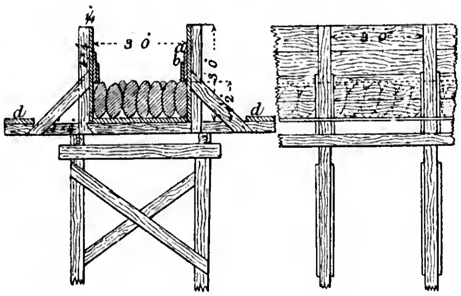


FIG. 112.



PAVING FOR SLUICES.

Another mode of paving is with pine blocks, 12 to 18 in. sq., cut across the grain of the wood, and 10 to 12 in. high. They are arranged as shown in Fig. 113, secured by a plank $1\frac{1}{2}$ in. thick $\times$ 6 in. high, nailed to the lower part of the blocks with headless nails, which stand up about 1 in., the succeeding blocks being driven down on the projecting nails so that they come close to the cross-piece. When the sluice has thus been filled with blocks, the side lining *a* is introduced. The spaces between the rows of blocks correspond with the $1\frac{1}{2}$-in. cross-pieces. The wood preferred at Smartsville is that of the "digger" pine (*Pinus Sabiniana*), and the blocks are cut 7 in. thick. A run lasts 20 to 30 days, when the bottom becomes so uneven that repairs and a clean-up are necessary.

Sometimes the heaviness and character of the wash-dirt compel the use of riffles laid longitudinally, instead of horizontally. The best are old railway-rails, when procurable; but a moderately good substitute may be made by covering wooden rails with strap-iron. Iron rails are laid close together, easily placed and easily retained in place, and give excellent results.

With regard to the relative claims of these several kinds of riffles:—Wood is expensive to build, presents the least catching surface, and lasts but little more than a month, the rapid wear rendering it likely that the gold may be ground out and washed away. Stone is the cheapest material, but expensive to pack in and remove; it wears slowly, and may be most conveniently used outside the tunnel, where room for piling the stones is at hand, and it presents the greatest opportunities for catching the gold, so that on the whole it is probably superior to wood. Iron rails have perhaps given the best results of any, and are becoming very popular.

Under-currents.—In setting out the sluice, provision will have been made for a sufficient number of under-currents. These, as shown in Fig. 114, may be likened to shallow ponds *c*, varying in form from oblongs or triangles to no regular shape, and in size from 10 to 40 ft. wide and 30 to 100 ft. long. They are put outside the tunnel, as circumstances of the ground will permit, about 75 to 100 ft. apart, the main object being to secure a space of some 500 to 1500 sq. ft., without much regard to its exact shape. The duty of the under-current has been already explained on p. 867. The sand and water are conducted into it by boxes 15 to 18 in. wide, placed in the bottom of the sluice, the outlet being fitted with a grating

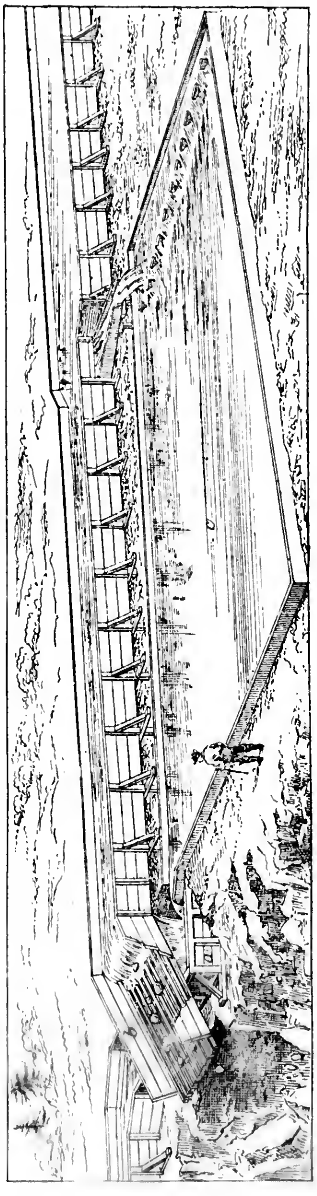


Fig. 114.

Hydraulic Under-current.

of 1-in. square steel bars set 1 in. apart. The gold-bearing muddy waters thus rush into the under-current at considerable velocity, and spread themselves out over its broad surface, which is furnished with riffles of different kinds, whose effect is to check the current, and cause the deposition of the gold and heavy matters, the former being caught by the amalgam and mercury placed there for the purpose. The riffles are arranged in such a way that the removal of a few slabs enables all or any part of them to be taken up. The grades of under-currents vary from 10 to 17 in. per 12 ft. Being very wide, check-boards are set at the upper end, to distribute the stream as evenly as possible over the whole floor; and as a considerable quantity of water is thus withdrawn from the sluice, its width is commonly reduced by 6 to 12 in. for the length of the under-current, resuming the full width again beyond. The lay of the ground and the amount of grade will determine whether the under-current shall be all on one side, on alternate sides, or on both sides at once of the sluice; in the last mentioned case, the sluice must be narrowed twice as much.

The discharge of the sluice and the under-current is usually made into a drop-box *a* (Fig. 114), which is much wider than the sluice, built of stout timber to withstand rough usage, and covered at bottom with a heavy stone paving, 4 or 5 ft. below the level of the sluice, and deeper than the continuation of the sluice, so as to serve as a receptacle for heavy matters. The depth of the drop is often ruled by the length of the under-current, which generally discharges into it over the side; but occasionally it is governed by the lay of the ground, so that the under-current will discharge from an end sluice. When a fall of 40 to 50 ft. is possible, the drop is placed directly under the sluice, which is continued either from one side at right-angles to its direction above, or, when the ground allows, in the same line, the continuation of the sluice being merely a contraction of the drop-box.

Grizzlies.—The "grizzly" *b* (Fig. 114) is a projection of the main sluice beyond and over the drop-box, and is an admirably simple contrivance for getting rid of the boulders and stones, which contain no gold, require much water, and only wear out the sluice. It can be availed of only when there is abundant natural accommodation for the débris thus ejected. The projection of the sluice over the drop-box is floored with railway-rails set 6 in. apart, and is inclined at an angle of 25° to 30°, to give the large bodies sufficient impetus to ensure their passing over; while everything small enough to go between the rails finds its way into the drop-box.

General arrangement.—The under-currents, drops and grizzlies are repeated as often as circumstances permit or require. At one works, there were 10 miles of sluice 4 to 6 ft. wide, and 23 under-currents 10 to 40 ft.

wide. A sluice intended for running off and re-washing the tailings that had been accumulated for 20 years was 6 miles long, 16 ft. wide, and 12 ft. high, built of heavy lumber, and anchored to the bed-rock with iron bolts. It was divided into two compartments, one 10 ft., the other 6 ft. wide, both being used when water was abundant, only one when it was scarce, or the other was being cleaned up.

On the North Bloomfield Company's workings, the arrangement of the sluices and under-currents is as shown in Fig. 115. A sluice paved with rock starts from the mouth of the tunnel *a*, and thence a variety of cuts and sluices conducts the current over several under-currents set on different grades, paved in turn with rock, blocks, and longitudinal riffles covered with strap-iron. The grizzlies used are made of 4-in. × 1-in. wrought iron, set on edge. The discharge from the under-currrents is taken up by the main sluice and subsequently redischarged over the succeeding under-currents, till the last sluice and under-current deposit the tailings finally in a cañon. The under-currents are as follows:—

1. Size, 24 × 36 ft.; grade, 13 in. per 12 ft.; chute, 2 ft. wide at opening, contracted to 10 in.; iron rail riffles. Yield of amalgam of the various compartments:—*b*, $108\frac{1}{2}$ oz.; *c*, $83\frac{3}{4}$; *d*, $46\frac{1}{2}$; *e*, $31\frac{1}{4}$; chute, $46\frac{1}{4}$; total, $316\frac{1}{4}$ oz. in three clean-ups.

2. Size, 24 ft. × 24 ft.; grade, 12 in. per 12 ft.; chute, $2\frac{1}{2}$ ft. wide at opening, contracted to 2 ft.; iron rail riffles. Yield:—*b*, $48\frac{3}{4}$; *c*, $36\frac{1}{4}$; *d*, $20\frac{3}{4}$; *e*, $23\frac{1}{2}$; chute, 14; total, $143\frac{1}{4}$ oz. in two clean-ups.

3. Size, 24 ft. × 36 ft.; grade, 15 in. per 12 ft.; chute, $2\frac{1}{2}$ ft. wide at opening, contracted to 2 ft.; rock riffles. Yield:—*b*, $50\frac{1}{2}$; *c*, $35\frac{1}{4}$; *d*, $18\frac{1}{2}$; *e*, 16; chute, $8\frac{1}{2}$; total, $128\frac{3}{4}$ oz. in two clean-ups.

4. Size, 20 ft. × 36 ft.; grade, 12 in. per 12 ft.; rock riffles. Yield, $71\frac{3}{4}$ oz.

5. Size, 24 ft. × 24 ft.; grade, 12 in. per 12 ft.; chute, $2\frac{1}{2}$ ft. wide at opening, contracted to

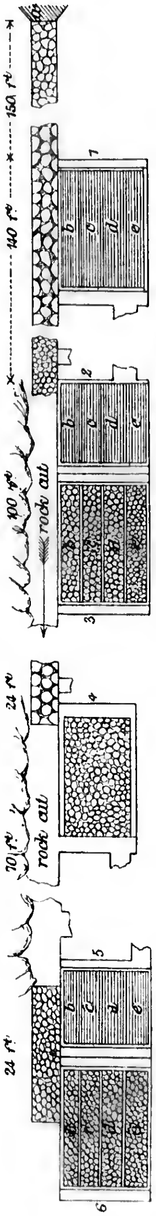


Fig. 115.

General Arrangement of Sluice, Drops, Grizzlies, and Under-Currents.

2 ft. ; riffles, 4-in. × 1¼-in. lumber covered with strap-iron and placed 1 in. apart. Yield :—*b*, 5 ; *c*, 8½ ; *d*, 5 ; *e*, 6½ ; total, 25 oz. in one clean-up.

6. Size, 24 ft. × 36 ft. ; grade, 17 in. per 12 ft. ; chute, 2½ ft. wide at opening, contracted to 2 ft. ; rock riffles. Yield :—*b*, 8 ; *c*, 5 ; *d*, 3¼ ; *e*, 3 ; total, 19¼ oz. in one clean-up.

The water used was 350,000 miners' "inches" of 24 hours each ; the total yield in 6 months was about 700*l.* worth of gold, of which about 630*l.* were taken from the first 150 ft. of the sluice down to the first under-current, and the balance from the remainder of the sluice.

Tail-sluices.—Of the immense mass of material washed into the sluice, but a small portion only is removed by the grizzlies, and all the remainder has to be disposed of. For this purpose, "tail-" sluices are run, if possible to a large river which will be capable of carrying away the tailings, or failing that to a smaller stream or a ravine. The tail-sluice must be stoutly and securely built, at the same time that it is easily taken down and transported as the exigencies of the case may require. Nothing needs more careful attention than the tail-sluice, for the body of barren material which has to be got rid of is so enormous, that rivers 500 ft. wide, 14 ft. deep in mid-channel, and with a fall of 18 ft. per mile, have been quite filled in 21 months of hydraulic washing; and it must be borne in mind that the moment it is impossible to get rid of the tailings, the works must be shut up.

Blasting.—The removal of the bank of gravel which is to be washed should be effected as far as possible by the aid of water alone ; but under certain circumstances, water may not suffice for the operation, as, for instance, when the gravel is very hard or cemented, or the bank so high that the nozzle cannot safely be put within close enough range, or for the purpose of accelerating the action of the water. In such cases, recourse is had to blasting, with the object of shaking and loosening the earth.

There are two ways of effecting the blast, either by a shaft or by drifts. In the former case, the shaft is either enlarged somewhat at the bottom, or a few little drifts are run from it ; the effects of such blasts being necessarily restricted to a small area, they are fit only for limited operations. Such shafts are occasionally used to loosen the upper gravel when the bottom stratum is a tough cement. In this way, the top is worked off first, and the bottom afterwards blasted by cross-drifts. They are usually 4 to 5 ft. in diameter, and are tamped with the material excavated. In the latter case, a number of drifts are run in proportion to the extent of ground to be blasted—which may be of almost any desired size. Egleston recommends that the main drift should be as small as it can well be worked, say 4 ft. high by 3 ft. wide, of the same length as the bank is high, and crossed by one or more auxiliary drifts, according to the size of the blast, one placed across the end and about half as long as the main drift, the second (if only two) across the middle and about one-third as long as the main. For a bank 80 to 120 ft. high, about 600 kegs of powder of 25 lb. each will be needed, of which there should be distributed two-thirds in the cross drifts at the end of the main drift, and one-third in the half-way cross-drift. A bank of 80 to 85 ft. will take 400 to 500 kegs; one 250 ft. high, 1500 to 2000 kegs. Bowie says that the main drift should be run for a length equal to two-thirds the height of the bank, and cross-drifts from the end of the main drift should be carried parallel with the face of the bank, the length being determined by the extent of ground to be blasted. A single T is all that is needed. The powder needed will vary according to the character of the bank and gravel from $\frac{1}{2}$ to $\frac{2}{3}$ keg (minimum) per 1000 cub. ft. of ground, which may be estimated as the height of the bank × the length of the main drift × the length of the cross drifts. The quantity of powder used should in any case be thoroughly sufficient to do the work, and had better be in excess than too little, as a blast inefficiently performed will not repay the cost and trouble of cutting the drifts.

Usually the powder is emptied out of the kegs into long boxes, which are then provided with fuzes at intervals corresponding to about 50 kegs, this plan tending to secure the complete and simultaneous combustion of the powder. When there is water in the drifts, these boxes must be well tarred, and the holes for the fuzes should be made in them and closed and coated with wax. Sometimes the heads are simply knocked out of the kegs and a fuze is placed in each, but the uncertainties of simultaneous combustion are then increased, by reason of the greater number of fuzes necessary. When the fuzes have been fixed, wires connecting with the battery are laid in place, and the main drift is securely closed at the first cross-drift by means of stout timbers, and then filled up to its mouth with damped sand. The fuzes are fired by an electric battery. A variety of explosives have been tried for blasting, but powder is the general favourite, on account of safety and ease of transportation.

Giant powder is much used for breaking up the boulders found in hydraulic banks, so that the fragments will pass through the sluices. The cartridges are broken open and the powder poured on to the rock, and sometimes built over with clay to hold it in place or increase the effect of the blast, a fuze and cap being used to explode the charge. Boulders which could not be reduced by sledge hammers, nor blasted by black powder without drilling, are thus easily broken down to such sizes that they will be carried away in the sluice. Pipe-clay also is now overcome by blasting with giant powder. The lumps of clay rolled down from the face of the washing are bored to the centre by a clay auger, and charged with $\frac{1}{4}$ or more of a cartridge of giant powder, with fuze attached. The shots are fired by a hot-iron and rod. This disintegrates the masses so that the water can completely reduce them.

Conduct of Operations.—When everything has been made ready, the washing operations commence. The first step is to remove the upper timbers of the shaft to a depth of some feet, and to shape out the ground around the shaft into a basin, the water and dirt being all washed down the shaft and through the tunnel, and helping to fill up the spaces between the riffles, and the cracks and openings in the sluices. This basin must be shaped as rapidly as possible, so as to get a space for the nozzles to work ; but care must be taken not to choke the shaft. The successful future working of the bank depends in a great measure upon the care bestowed on the preliminary opening. To wash down a bank, two nozzles are commonly used, and made to play at the foot of the bank, at an obtuse angle, one on either side. Sometimes a third nozzle will be needed to wash away what the other two bring down, and sometimes one does the cutting down and a second the washing away. At first the water spreads and splashes all abroad, but soon it commences to bury itself, and gradually works out an arched cave in the bank, whose depth is regulated by the judgment and experience of the miner.

When one cave is finished, a second is commenced ; and when several are made, the portions left standing between them are washed away, and the upper part of the bank falls down. The operation is illustrated in the frontispiece. The fallen material is washed into the sluice or sluices connecting with the top of the shaft, and thence into the tunnel (if there be one, which is not the case in the example shown) and sluices for extracting the gold. At Reefton, New Zealand, it is finally run over the blanket-tables shown in Fig. 116. It is important that the supply of earth should be kept as regular as possible. The ground is worked in the shape of a funnel, whose leg is the shaft; and sometimes the shaft itself is washed away, so that only a deep basin exists, with the tunnel for an outlet at the bottom. It is most economical to work several nozzles in the same general direction. Rubbish which is not worth putting through the sluice-boxes should be deposited where it may remain and not need removal. Boulders too large for the sluice must be broken down by hammers or powder.

An important precaution in washing a bank is to keep its face square, as it is then cheaper, easier, and safer to work. If the banks are allowed to overhang, the men's lives are in danger from a sudden fall of earth, which they could not avoid. When the banks are very high, they are best worked in terraces of about 125 to 150 ft. high each ; 200-ft. banks are sometimes washed off at once, but they are very dangerous. The bank generally gives warning of an approaching fall, and the water should then be shut off, for if it be allowed to play upon the falling mass, the dirt would run, and the men might have great difficulty in avoiding it; whereas with proper precaution, the boulders only will run, and they can be seen and escaped. Falls, or "caves," as they are technically called, are usually effected before night, to give time for remedying accidents before the next day's work. In very large washings, work is

FIG. 116.

BLANKET-TABLES AT END OF HYDRAULICING SLUICE.

continued at night to run through the "cave," but in small ones night-work is unusual, except the pay-dirt be very rich, when, to use Egleston's own words, "the work is continued as much to prevent clean-ups [by other people] as to get the pay in a shorter time."

A method of moving very large boulders is to undermine them and let them roll. Boulders 6 ft. in diameter are sometimes moved thousands of feet in this way; but the plan is eminently dangerous, despite the possibility of judging what direction the rock will take. It is better to use a simple derrick, mast about 100 ft. high, set in iron sill, and supported by guys, and boom about 90 ft. long. This can be easily moved without taking down, and will lift anything up to 10 or 11 tons; larger boulders must be blasted. The power used for the derrick is generally a simple overshot water-wheel.

When commencing with new sluice-boxes, light gravel must be washed through with a full head of water for a day or two, to fill up the greater part of the spaces and hollows in the paving, otherwise the mercury when added would sink out of reach of the gold. Before beginning the washing proper, the current of water is reduced, and 500 to 600 lb. of mercury is introduced for a sluice 5000 ft. in length. The bulk of this will be placed in the upper portion of the sluices, as the stream always washes it down more or less; and it should be sprinkled so as to fall in little globules. The whole quantity is not introduced at once, but in little driblets, till it is visible behind the riffles. Sometimes the quantity is progressively diminished during the final weeks of a "run"; but a better plan is to carefully watch the sluices, and add whatever may appear necessary up to the last moment. The sluices are usually attended to twice a day, and a little mercury is added.

General clean-ups are not usually undertaken more than once or twice a year, when the whole operations are suspended, and the paving and riffles are removed from the sluices: but partial clean-ups, especially in the upper part of the sluices, occur about once a fortnight. When the clean-up is to be made, the sluice is run empty, and sections of the paving are taken up in succession, commencing at the top. Riffles are then put across the sluice, a little mercury is poured in to collect the amalgam, and the fine heavy matters collected are washed down with a small stream. The amalgam is scraped up, as in any other sluice. To guard against stealing, the sluices are sometimes filled with gravel before turning off the water, and this is removed by hand, section after section as the cleaning up progresses; in other cases, a stream of water is kept running through, or armed sentinels are placed on guard.

Working Results.—Under favourable conditions for hydraulic washing, two men can do all the work required, in a washing that uses 300 miners' "inches" of water. Under such circumstances, 1 pipe will break down as much as 3 can wash away; on the other hand, 3 pipes are sometimes required to break down what 1 can wash away. The water is generally considered capable of carrying away $\frac{1}{8}$ of its own weight of gravel.

The average cost for the La Grange Company, according to Bowie, may be roundly stated as follows:—

Per oz. of Metal produced.	s.	d.
Water	5	10
Labour	28	4
Material	7	6
Officers	3	11
Contingent expenses	1	1
Taxes	0	4
	47	0

Per cub. yd. treated.	d.
Water	0·4
Labour	1·8
Material	0·5
Officers and contingent expenses	0·3
	3·0

The above refer to light pressure and low grade. For heavy pressure and 4 per cent. grade, an example may be found in the North Bloomfield Company's figures, per oz. of metal produced :—

	s.	d.
Labour	16	0
Blocks and lumber	2	0
Explosives	4	0
Materials	3	8
General expenses	2	11
Water	8	0
	36	7

The following promiscuous costs per yd. may also be quoted :—3*d.*; $1\frac{1}{2}$*d.*; $1\frac{1}{4}$*d.*; 1*d.*; 1*d.*; averaging from 1*d.* to $2\frac{3}{4}$*d.* per cub. yd.

Of the yield from hydraulic workings, those lying between the Middle and South Yuba have averaged, according to Laur, 8*d.* per cub. yd., and according to Prof. Silliman, 15*d.* per cub. yd. Various yields have been :—2*s.* $11\frac{1}{2}$*d.*; 2*s.* 6*d.*; $12\frac{1}{2}$*d.*; $7\frac{1}{2}$*d.*; $6\frac{1}{4}$*d.*; 5*d.*; $2\frac{3}{5}$*d.* The last-mentioned figure refers to the Gold Run district, where all the conditions were extraordinarily favourable. The average yield of the Smartsville gravel is stated by Whitney at about 23c. ($11\frac{1}{2}$*d.*) per cub. yd.

The hydraulic method has been in use on the Sierra Nevada over 20 years, and the experience of this period affords a means of judging the value of the gravel and the profit in working it. The general results have been very satisfactory. Wherever the richer blue gravel has been accessible, as at the Flats, Badger Hill, and below San Juan, it has, with very rare exceptions, paid profits, and sometimes large profits, to its owners. The top gravel, though much poorer than the blue, has often been found very rich in streaks (due to concentration by surface streams), and has, in general, paid large sums of money to the ditch companies furnishing the water, leaving something besides for the owners of the ground. There are few trustworthy records showing in detail the costs and profits or losses of the business in the earlier years of hydraulicing; but so far as the top gravel is considered, the price paid for the water used in mining is some indication of the result obtained.

In early years, the price of water was 25c. ($12\frac{1}{2}$*d.*) per "inch" for 10 hours' flow. This price has fallen, by gradual reductions, to 20c., $16\frac{2}{3}$c., $12\frac{1}{2}$c., $10\frac{1}{2}$c. per "inch" for 10 hours, the price at present varying from 8c. (4*d.*) to $12\frac{1}{2}$c. ($6\frac{1}{4}$*d.*) per "inch" for 10 hours, or twice that price for 24 hours. In many claims, in which top gravel only was washed, the water was paid for at 20c. to 25c. per "inch" for 10 hours, and instances are reported in which, after paying these charges, the owners retained handsome profits; such cases were, however, exceptional. On the other hand, it is well known that under the high rates charged for water in early days, many attempts to wash the top gravel resulted in loss.

At the present day, where the top gravel only is washed, it is thought to do very well if it yields 10c. to 15c. (5*d.* to 7½*d.*) per "inch" of water for 10 hours. On the North Bloomfield Co.'s mine in 1870–71, the yield of surface gravel was 16c. (8*d.*) per "24-hour inch," or $6\frac{6}{10}$c. per "10-hour inch." From 1870 to 1874, the yield was only $13\frac{6}{10}$c. per "24-hour inch," equal to $5\frac{68}{100}$c. per "10-hour inch." In 1875, the top gravel, including a little blue gravel, but nothing within 40 ft. of the bed-rock, yielded $19\frac{2}{10}$c. per "24-hour inch," or 8c. per "10-hour inch." It is quite probable, however, that the water in this mine, furnished as it is from the company's own ditch, is much more lavishly used than in mines where it is purchased, and the relation of water to product would, on that account, be an unfair criterion for other mines. At Columbia Hill, where only top gravel has been washed, its yield in several instances has varied from about 20c. (10*d.*) to 58c. (29*d.*) per "24-hour inch," affording in the instance last referred to exceptionally good profits.

Some of the mines below San Juan afford the most satisfactory examples of the results of washing the entire bank, including together the top and bottom gravels. The record of their observations during the past 4 years, where they can be obtained, furnish the best data for judging the value of the ground. Of this portion of the channel, some 2 or 3 miles have been already washed out. The American mine has been worked for a length of about 3000 ft. along the channel. The width of the cut, from rim to rim, is probably 1000 ft., and the workings about 140 or 150 ft. From some data furnished from the company's books, a few years since, it appears that the gross product of the mine from December 9, 1860, to August 6, 1872, was $1,241,240 30c. (258,591*l.* 14*s.* 7*d.*). The water used in this period was 1,454,174 "inches" of 10 hours, and the yield per "10-hour inch" would accordingly be 86c. (3*s.* 7*d.*). The price paid for the water varied from 16⅔c. to 12½c. per "10-hour inch," amounting in the aggregate to $218,749 58c. (45,572*l.* 16*s.* 7*d.*), or 30·6 per cent. of the whole working expense. The last-named item was $714,771 04c. (148,910*l.* 12*s.* 8*d.*), and the nett proceeds $526,469 27c. (109,681*l.* 1*s.* 11*d.*), or 42·41 per cent. of the product. In 1871, Hamilton Smith estimated that the yield of this ground amounted to 24c. (1*s.*) per cub. yd., and that each linear ft. of channel worked had paid at least $750 (150*l.*).

These examples might be supplemented by others, but enough has been said to warrant the conclusion that the top gravel alone usually contains gold enough to pay the expenses of mining, and leaves a profit for the owner of the water; and, further, that where the blue or bottom gravel has been washed, it has, with very rare exceptions, made satisfactory profits for the owner; finally, in order to reach the blue gravel, the top gravel must be removed.

Four companies at Howland Flat and Potosi—the Down East, Union, Hawkeye, and Pittsburgh—took from 2,365,000 sq. ft. of surface, \$2,251,653 95c. (470,094*l.* 6*s.* 5*d.*), the pay-gravel being estimated at 4½ ft. in thickness. This would give an average of 95c. (3*s.* 11½*d.*) per sq. ft. of surface, or \$5 70c. (23*s.* 9*d.*) per cub. yd. of gravel washed. This material was mined, it is stated, at a cost of 47c. (23½*d.*), leaving a profit of 48c. (2*s.*) per sq. ft. At Grass Flat, in the Pioneer Company's ground, the yield per cub. yd. of gravel is said to have been \$1 59c. (6*s.* 7½*d.*).

At Allan's Flat, Yackandandah, Victoria, the ground washed off was about 30 ft. deep, the water used was 500 gal. a minute, and the inclination of the sluice was 1 in 25; 3 men worked 150 cub. yd. per diem. The daily expenses of a claim were:—

	£	s.	d.
3 men at 8*s.*	1	4	0
360,000 gal. of water at 0·33*d.* ..	0	10	0
Wear and tear	0	6	0
	2	0	0

Consequently a yield of ⅜ gr. of gold per cub. yd. covered all expenses.

A hydraulicing claim on Dunedin Flat, Kumara, New Zealand, yielded 1735 oz. of gold from a block of 22,403 cub. yd., or an average of 31 gr. per cub. yd., working a face 35 ft. deep. Shares in this claim sell readily at 400*l.* each.

Losses.—The basis on which hydraulicing is pursued, at least in America, is that it pays better to treat a great quantity of gravel with a great loss of gold than a small quantity with a small loss. The consequence is that the waste of gold is really enormous. The coarse gold is probably caught pretty effectually; but the greater part of the fine and rusty gold is undoubtedly lost, and it is not too much to say that 15 to 20 per cent. of the total amount of gold present in the gravel is by this system scattered throughout the watercourses of the country in such a way that it is lost, not only to the miner of to-day, but to succeeding generations. One party who took the trouble to wash some of their tailings in a rocker got \$5 (1*l.*) worth of gold from 60 bucketfuls of tailings, or an average of 4*d.* per bucket. This loss does not consist either of gold alone. Of the mercury put into the sluices for amalgamating with the gold, 10 to 25 per cent. passes away with the tailings. This is due partly to the flouring of the mercury, from the constant attrition to which it is subjected; but is also owing in a great measure to carelessness in watching the sluices and keeping them in repair. Instances are not unknown where many lb. of mercury have been taken from a single pocket where it had gathered in the tailings. Considerable profit has been derived in some cases from rewashing deposits of tailings, the conduct of the process being rendered vastly cheaper than other sluicing, by reason of the abundance of mercury present.

As to the loss of gold in the operations carried on in the Smartsville district, in the opinion of some well-informed miners, it is not over 20 per cent., while others set the amount as high as 50 per cent., and express a belief that the bars of the Yuba, into which the tailings are run, would be found to be as well worth working as they were in 1849.

Seam diggings.—In some districts, innumerable small stringers and seams of quartz, frequently much decomposed, and all carrying more or less gold, are found permeating a soft easily-disintegrated slate formation; and it has been proved feasible to treat this formation by hydraulic washing, as the gold has been thoroughly liberated from its matrix by natural processes. Hydraulicing is conducted on somewhat different principles in the case of seam diggings. The sluices are set at a steep grade, even 18 in. per 12 ft.; the whole formation cannot always be washed away indiscriminately, for sometimes barren earth only would be passing through the sluices, and at other times the gold might be too plentiful to be properly caught. The pay-dirt does not run horizontally, as in gravel deposits, but vertically, in a narrow channel of quartz seams related to a well-defined wall or fissure, which always pitches at a steep angle, and often dissects all the veins on one side. The auriferous rock is not always closely confined between two perfect walls, but is often spread out 20 to 50 ft. on one side of the main fissure. It is commonly associated with a series of lenticular masses of quartz, crossing or lying parallel with each other, and having the same dip; also in the form of chimneys, where courses of seamlets cross each other. There is a great tendency to form lenticular masses, often measuring only a few ft. each way, but occasionally 40 ft. long and wide, and a few ft. thick. When near the surface and the ground is decomposed, and the pay-seams are numerous and widely distributed, it is best to hydraulic away the whole hill; but as soon as the deposit is beyond the reach of water, the seams must be followed by shafts and drives, and the working generally assumes the character of an ordinary vein-mine, the stringers becoming harder and more strongly marked as the region is reached where surface influences have not been at work.

A somewhat similar plan was adopted by Stackpoole in dealing with a soft granite dyke containing veins of poorly auriferous quartz, at Wood's Point, Victoria, for an account of which the author is indebted to A. B. Ainsworth, C.E., of Alexandra. Water to the extent of 6 or 8 sluice-heads (say 1200 to 1600 gal. a minute) was available at an altitude of about 80 ft. above the creek draining the outcrop of the dyke. The loose stuff was run through sluice-boxes with false bottoms, and the quartzose débris was crushed. The lumps of quartz were turned into a paddock at the end of the sluice-boxes during the sluicing operation, by means of a "grizzly" made of timber rails 3 or 4 in. apart. A couple of forkers were employed in the paddock pitching away the stones and rocks known to be valueless. In the course of 2 or 3 weeks, some 300 or 400 tons of material accumulated in the paddock; this, trammed to the stamps, and crushed at an average cost of 1*s.* 6*d.* per ton by water-power, yielded 2 dwt. of gold per ton, in addition to the loose gold caught in the sluice. About 9 men were occupied in the sluicing and paddocking.

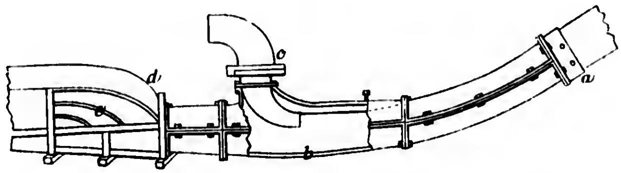
Crushing process.—In some places where water has not been found in sufficiently constant abundance, and also where difficulty has been encountered in finding outlet for the tailings, hydraulicing has been superseded by other methods. One of these consists in removing, not the whole depth of the auriferous ground, as is necessitated by hydraulic operations, but only a few ft. of the richest stratum from the bed-rock upwards. This permits a portion of the gold to be extracted from ground which must otherwise lie unworked, and in some instances the immediate return for outlay is much greater than would be the case with hydraulicing; but the less auriferous ground left will probably be found too poor to pay for working alone by hydraulic or any other process at a future date. The pay-dirt extracted has to be put through a crushing process in order to liberate the gold. Raymond mentions a Californian company as the only one working successfully in this way, and gives the following particulars of their operations:—Men employed, 25; wages, 12*s.* per day; output, 40 to 50 carloads per 24 hours, according to nature of ground; motive power, water—75 in. with a head of 80 ft., projected against a 10-ft. hurdy-gurdy wheel.

		s.	*d.*		*s.*	*d.*		*s.*	*d.*
Average yield per	carload (19½ cub. ft.),	15	8½;	cost,	8	5½;	profit,	7	3
,, ,,	ton of 2000 lb. ..	19	7½;	,,	10	7;	,,	9	0½
,, ,,	cub. yd.	22	0½;	,,	12	1;	,,	9	11½

Drake's cement-mill (see p. 898) is sometimes applied to this purpose. It is so set in connection with the sluice-boxes that such portion of the gravel as may have become fine by the washing and blasting flows through a grizzly leading under the mill to the opposite end, while the hard gravel passes into the mill; it is there disintegrated, discharged into the sluice, and passed to the under-currents. This obviates the necessity of having "drops" to break up the material. It is stated that "the whole expense of working cement by this machine, when put in with cars, is about 25c. (12½*d.*) per sq. yd., when working 1000 to 2000 tons per diem. When put in through the sluices, some 5000 tons or more a day can be put through at a cost of between 2c. and 3c. (say 1¼*d.*) per yd."

Hydraulic elevators.—Cranston's hydraulic elevator (Fig. 117) is devised to overcome the difficulty of washing gravel lying below the natural outlet of the basin that contains it. A closed flume *a* is placed on an upward incline, and fitted with a horizontal one *b* of cast-iron, into which is introduced a hydraulic nozzle *c*, pointing in the direction which the gravel is required to take. The horizontal portion of the apparatus has an open end *d* behind the nozzle by which the gravel and water enter. The gravel is washed in as it might be into any other flume, but a grizzly *e* is arranged to turn off the large stones at the mouth. The gravel and water pass from the closed flume into an ordinary sluice at the top, and

FIG. 117.



CRANSTON'S HYDRAULIC ELEVATOR.

it is said that they have been run through the flume as thick as the water will carry the gravel through a sluice set on a 24-in. grade, and that it was found impossible to choke the apparatus by any head of water it was calculated to carry; also that it washes the gravel as well as ½ mile of ordinary sluice would do. Under-currents are placed at a short distance down the sluice from where the elevator-spout discharges into it, drawing all the heavy materials—gold, mercury, &c.—from the sluice as soon as it has time to settle from the agitation produced by the discharge. This under-current is so near the head of the sluice that it saves most of the gold, and can be cleaned up every day if desired, without stopping the apparatus. To recover the elevating water, and re-use it for driving the gravel into the machine, a settling-tank is made on the side of the sluice, just far enough down from where the spout discharges to allow the surface water to become settled a little. The side of the flume next the settling-tank is cut away, and bars are placed lengthwise at short intervals apart across the opening into the flume. The surface of the water containing but little gravel flows over into the settling-tank. The bars prevent the stones and boulders from passing over, and keep them in the main flume. It is claimed for the process that wherever hydraulic pressure can be had —say 100 to 300 ft.—a mine can be worked 20 to 50 ft. deep to as good advantage as through an open cut or tunnel.

The following general instructions may be useful. The machine should be set 5 ft. deep in the bed-rock, in a timbered room or box. The water-lifter should be set on one side of the box, 2 ft. lower than the elevator, and should be set before the elevator, and used as a pump and to run out the dirt, gravel, &c. in the excavation where the elevator is set. The elevator should be set on bed-pieces put crossways of the shaft or box. The box should be for a 12- or 16-in. machine, 12 ft. long and 6 ft. wide in the clear inside, so as to allow of turning a wrench between the machine and the side of the box. For a 20-in. machine, it should be 16 by 7 ft. inside. The water-lifter should be set outside of this box. The incline of the discharge spout is 45°; 17 in. in length of this spout make 1 ft. high. This spout should be made of 3-in. plank, and large enough for a set of blocks to go inside; and the top or lid should be held on by clamps, and not nailed; the bottom and two sides should be nailed together with 6-in. spikes. The spout should have a curve at the top, so as to discharge straight into the flume. This curve should be 8 ft. long, and should rise in its length 3 ft. for a 12- or 16-in. machine; for a 20-in. machine, it should rise 4 ft. in its length. In calculating the length of the discharge spout, deduct this amount; also deduct the curve in the discharge end of the machine, which is as follows: for a 12-in. machine, there is a rise in the machine itself of 18 in.; in a 16-in. machine, there is 26 in. rise; in a 20-in. machine, there is 4 ft. rise in the machine—so this much, with the curve on the machine, should be deducted from the amount required to rise, and the spout be made accordingly. The grizzly or feed-box should be—for a 12-in. machine, 3 ft. 9 in. long; for a 16-in. machine, it should be 4½ ft. long; and for a 20-in. machine, it should be 5½ ft. long. Its grade should be, in its length—for a 12-in. machine, 10 in.; for a 16-in. machine, 12 in.; and for a 20-in. machine, 16 in. The flume should be—for a 12-in. machine, 30 in.; for the top flume, with whatever grade the ground will admit of, giving sufficient dump. The feed-sluice in the bottom should be 24 in. wide, and should have at least 6 in. grade to 12 ft., and as much more as the ground will admit of. These grades will do for all the larger sizes; but the size of the flume should be as follows: a 16-in. machine wants a 3-ft. discharge and a 30-in. feed-flume; and a 20-in. machine wants a 4-ft. discharge-flume, and a 3-ft. feed-flume in the bottom. The sizes of "giants" required are as follows: a 12-in. machine wants a No. 2 giant; a 16-in. machine wants two No. 2, or one No. 3 or 4 giant; and a 20-in. machine wants two No. 4 or 5 giants. The main pipes should be the size of the machine or larger—that is, a 12-in. machine should have a 12- or 15-in. main; a 16-in. machine should have a 16- or 18-in. main—18 in. would be better; a 20-in. machine should have a 20- or 22-in. main. Forks or crotchets are better than distributors for the lower end of the main pipes, and want regular screw water-gates.

Concerning Cranston's elevator, Prof. Skidmore obligingly writes that it is most successfully used in working ground with a light grade. There are at least a dozen in use in California alone. He has not seen any treating gravel "considerably below the ground level." Those seen were dealing with ground about 3 ft. in depth, where the grade was so light that water would scarcely run. The elevator raised the gravel in one instance 18 ft., and in another 13 ft. to the sluice-box. Wm. T. Dewey says that a water-pressure of 180 ft. (miners' measurement) will give a lift of 15 ft., and 300 ft. a lift of 25 ft., and so on. Skidmore states that when he has seen the elevator in operation, the amount of water used has been 160 to 240 "inches," and the lift 13 to 23 ft.

Perry's elevator.—The working of Perry's elevator, which has already been alluded to on p. 525, is thus described by Warden Carew. The works consist of a drainage-race, pipes to lead head-water, an elevating-pipe, and sluice-boxes. The drainage-race is made of sheet iron. forming a pipe 30 in. diameter. At the lower end of the race, this pipe is laid on the surface of the tailings, and it is extended up the gully through a channel opened in the tailings, with just sufficient inclination to allow water to drain down the gully. This pipe is continued for a distance of 1500 ft. up the claim, and is at that point a considerable depth from the surface of the tailings, and 2 or 3 ft. into the bed-rock. By means of this race, the object sought for—thorough drainage—is effectually secured, and the race can be now extended as the workings advance up the gully, by simply cutting a channel in the rock, the distance and depth required, and covering it with suitable material. Near the present head of the drainage-race, operations at sluicing the ground have been commenced. A large open space was first made down to the rock bottom, and the elevating apparatus placed in position. This consists of a double pipe 15 in. diameter, made of sheet iron, joined with a half circular cast-iron elbow of larger diameter than the pipe, and perforated at the angle with an aperture of 12 or 14 in. diameter. The elbow is placed in a hollow, or shallow well-hole, in the rock, and the ends rise nearly perpendicular 12 or 15 ft. above the surface of the tailings. One end of this pipe is joined to another pipe of the same diameter, which conveys water from a supply-dam situate at an elevation of 294 ft., thus affording great pressure. The other end of the pipe is made to discharge into the head of a long line of sluice-boxes supported on trestles over the bed of the gully. When water is let in from the supply dam, it passes down through the water-pipe, and then rushes up the elevating-pipe, drawing, as it does so, through the aperture in the elbow, all gravel, cement, earth, or water within reach. With a sufficient supply of water, the process seems capable of lifting an enormous quantity of stuff, and it is projected up the pipe with immense velocity, estimated at a mile a minute, by which means all unbroken lumps of cement strike a thick plate of iron placed for that purpose at the top of the pipe, and, by force of the blow, become pulverized. Everything reaching the head of the pipe then flows through an aperture into the sluice-boxes, which, being raised as explained, can be so arranged as to discharge débris at any locality or distance, as occasion may require. Another appliance is a line of 15-in. piping, about 3000 ft. in length, which conveys water from a lagoon at the head of the gully to near the face of the workings. The pipe is there fitted with a patent nozzle, with which the water is played upon the face, sides, and bottom of the workings, and forces the earth and tailings in large quantities towards the aperture in the elbow of the elevating-pipe, whence all is drawn up the pipe and deposited in the sluice-boxes. When the claim is properly opened out, and the process

Fig. 118.

Perry's Hydraulic Elevator at Work.

complete, the gravel and earth will be first elevated on to a platform by means of buckets travelling on a band, worked by a turbine wheel, and be there discharged on to a grating for the purpose of separating all large stones; these will fall on to a travelling chain-belt, and be deposited in any convenient spot out of the way of the workings. The fine stuff will fall through the grating on to a hopper at the base of the elevating-pipe, be drawn through the aperture, and lifted a further 20 to 40 ft. as may be necessary, to afford sufficient space for deposit of débris from the sluice-boxes. The apparatus is shown in full work in Fig. 118.

Booming.—The term "booming" is applied, in the Western States of America, to an operation much resembling the old process of "hushing," as used in Yorkshire for discovering lead-lodes. A reservoir is first constructed at the head of the ground to be worked; into this, water is conducted, from the most convenient source still higher up, by flumes or ditches. These reservoirs vary in size from a small pond to an acre or two lake, and the ditches are often 8, 10, and 12 miles long. When the basin is full, and a continuous head of water is in running operation, gates are opened, letting loose the whole volume of the liquid, which tears down the mountain side in a huge volume, sweeping everything before it, carrying tons of boulders, gravel, and dirt down to the gulch below. If auriferous ground is to be worked, a long and massive wooden flume is built at the foot of the hill, into which the débris is carried, with all the force of the falling waters and the sand and rocks washed along in its course, while the gold is deposited by its own gravity, behind the riffles in the bottom of the race. These flumes are often thousands of feet long, and as rocks of all sizes and weights are carried along in them, they must be built with great strength and solidity, to withstand the immense wear.

The self-acting gate, now considered the best (whereby the opening and shutting of the gate of the reservoir is made automatic), consists of a water-box suspended in guides, the rope from which passes over two pulleys, one of 12 ft. and one of 5 ft., to the lower edge of the canvas gate (barred with strips of iron or 2-in. timber). When the water in the reservoir reaches the proper height, a small flume conducts it to the box, which, when full of water, has weight enough to roll up the canvas gate at the bottom of the reservoir from the bottom, allowing the water in the reservoir to issue through a gate (generally 4 × 6 ft. in size). By the time the reservoir is nearly empty, the water in the weight-box has discharged itself through holes made for that purpose in the bottom, and a weighted arm on the second pulley drops the gate to its place, when the pressure of the water keeps it in place water-tight. One man is now considered ample force to run a boom, and his duties consist mostly in clearing timber from the ground to be worked and in breaking the larger boulders into sizes small enough to go through the flume, which is usually 4 ft. wide with a grade of 1 ft. in 12 ft. The use of a boom permits the working of ground that could by no other means be made to pay. The experience of the Summit County miners goes to prove that, notwithstanding the large amount of water used and the velocity with which it rushes through the flume, the gold collects readily in the upper boxes of the flume, in which mercury is generally placed. Booming permits the working of claims that would otherwise be valueless.

Utilizing river-currents for Sluicing.—J. T. Thomson suggests the following method for utilizing the current of large rivers for gold-sluicing. A screw 8 ft. in diameter will give 8 H.P., and can be immersed and attached to any fixture. It will raise one Otago sluice-head of water (equal to 95 cub. ft. of water delivered per minute) to an elevation of 70 ft., or 7 heads 10 ft., without intermission. The screw may be made of timber, and can be put together by any blacksmith or carpenter. Minor scientific faults in its form are compensated by an excess of current-power. The accessories requiring skill in their construction are a brass force-pump and some indiarubber tubing. With a screw or fan 15 in. in diameter, with blades set at an angle of 20° to the disc, in a 2-mile current, the revolutions are nearly 1 per second; the pistons of the pump are worked by a crank, propelling the contents once per second; the diameter of the cylinder is ¾ in.; stroke of piston, 2·7 in.; quantity of water per stroke. 1·1925 cub. in., or 71·55 cub. in. per minute, or 59·5 cub. ft. or 368·9 gal. per 24 hours; cost 4 or 5*l*. The capacity and cost increase, of course, with the size. The whole apparatus is easily repaired, and can be removed at will.

Drawbacks to Hydraulicing.—The main difficulty with hydraulicing is to find an outlet for the refuse, and were it not for this, there would be greater activity in this description of mining. The difficulty, fortunately, does not affect all mines, as some have facilities for disposing of their "tailings" in valleys or gulches, without making use of rivers or creeks. One Californian company has spent a large sum of money in purchasing the land they required for their débris, and others no doubt will do the same. Two or three suits have been brought against hydraulic mining companies by farmers, who have had their land deteriorated in value, or rendered entirely valueless by the deposit from the mines, but all the suits have gone against them. Although no one can doubt really from the character of the deposit that the damage done is due to the action of the miners, the difficulty appears to be to fix the liability upon any particular companies. The damage done to the lands bordering on the rivers will sooner or later be settled, either by action of the Legislature, or by an arrangement between the parties interested; but the more serious question cropping up is as to the damage done to the navigation on the rivers and bays. This question is receiving the attention of the Federal authorities in Washington, at the instance of the Chief of Bureau of Engineering, who has reported that the arm of San Pablo Bay, separating Mare Island from Vallejo, and forming the Navy Yard Harbour, is filling, and that he attributed it to the system of hydraulicing. Steps have been taken to have a full investigation of the matter. When the mining companies realise that they have to combine upon some plan to dispose of their débris, other than in constructing a tunnel to carry it to the nearest river, the difficulty in most cases will not be of such a formidable character as to impede operations materially. There are large tracts of "tule" land which would be benefited by receiving these deposits, and the heavy adobe soils could be improved by a limited supply. An engineer who has studied the question thoroughly has lately written a letter to one of the local papers, and the following extracts will be read with interest:—

"For several years past I have made a special study of the subject of mining débris and its effect upon the harbours, rivers, and agricultural lands of the State. In 1870, I had occasion to make a reconnaissance of the Bear River country and its hydraulic mines. This year I made a detailed instrumental survey of the Yuba River and its tributaries, extending from its mouth at the city of Marysville to the head of the hydraulic mining belt in the Sierra. In this connection I have already surveyed, and otherwise examined, all the hydraulic mines located in the watershed of the Yuba, and depositing their tailings into the same. I am enabled, therefore, to submit a few leading facts and figures relating to this important matter, that may tend to disperse many of the random statements and positive misrepresentations that have been made to your Honourable Committee, either by parties grossly ignorant of the subject, or by parties holding large interests in hydraulic mines. One of your informants states, for example, 'that the value of farming lands destroyed by hydraulic mining, when compared with the value of the mines, is not over 2 per cent.,' and in the next sentence he declares that 'the débris of the mines is, on the whole, beneficial to farming lands.' Now, from accurate surveys made by the State Engineer of California, it has been ascertained that over 18,000 acres of valley land on the Yuba—land that was once the finest bottom land in the State—have been utterly destroyed and buried beneath the mining débris; so that now this vast area has been transformed into a barren desert of sand and slickings, alternating with impenetrable jungles of willow swamp. Probably as much if not more of equally good land has been similarly destroyed on Bear River. Although these lands have been exposed to sunshine and rain for years, they produce not a blade of grass—nothing but willows, and kindred semi-aquatic plants, that derive their nourishment chiefly from the stratum of water percolating underneath the surface, and not from the soil itself. This gentleman further says, 'fully 95 per cent. of the tailings are lodged in the cañons (gorges) or near the mines, and the remaining 5 per cent. finds its way down the lower portions of the mining rivers.' The reverse of this percentage would be nearer the truth. From the beginning of hydraulic mining down to the present time, the enormous aggregate of 162,000,000 cub. yd. of material has been sluiced out of the hydraulic mines into the Yuba and its tributaries; while the amount now retained in the river, above the valley, or lodged in the cañons, will not exceed 12,000,000 cub. yd. This we have from actual surveys. Thus 150,000,000 cub. yd. of solid material have passed the foot-hills, and have been deposited on the bottom lands of the Yuba, into the waters of the Feather and Sacramento rivers, the Bays of Suisun and San Pablo, and finally into the Bay of San Francisco. (One company alone—the 'Excelsior Hydraulic Mining Company,' at Smartsville—admit in a published circular that they have sluiced 18,600,000 cub. yd. into the Yuba.) To present to the mind this enormous mass of 150,000,000 cub. yd. of material in a more familiar form, it may be stated that such a mass deposited on a farm of 150 acres would cover it to a depth of 581 ft.; or if spread evenly 1 ft. in depth, would cover 93,000 acres, or 145 sq. miles of land, and absolutely destroy it for agricultural or any other purpose. The bed of the Yuba at Marysville is now filled up to the level of the streets of that city, where prior to the era of hydraulic mining there was a well-defined channel of clear water, 20 to 25 ft. in depth. The authorities of Marysville have just closed a contract amounting to $50,000 (10,000*l.*) for raising its levees, and protecting the city from the further encroachment of the mining débris. The Feather and Sacramento rivers have shoaled in a lesser degree, but still almost sufficiently to destroy their usefulness as highways of commerce. A re-survey of Suisun Bay, recently made under direction of the United States Coast Survey Department, has developed the fact that tules (*Scirpus lacustris*) are now growing at points where 15 years ago there were several fathoms of water. The complete filling up of the bay is a mere question of a few short years, after which San Pablo Bay will become the next settling reservoir, to be followed finally by the rapid shoaling of San Francisco Bay, and the eventual destruction of its harbour. These results are sure to follow; the laws of nature make them inevitable, unless, indeed, hydraulic mining is discontinued, or unless some adequate works be devised for arresting the tailings before they reach the valleys, or enter the navigable waters of the State. On this head, our survey has given us sufficient data to warrant the belief that such works are not only feasible, but entirely within the bounds of a reasonable expenditure of money.

"Your informant further avers that of the material deposited in the rivers, the farmers contribute 12 or 15 yd., where the miners contribute 1 yd., an assertion so palpably absurd as scarcely to admit of argument. The farming lands of California are exceptionally free from wash, the soil being generally of a resisting and tenacious quality, with a comparatively level surface. Moreover, nearly all the farming lands adjacent to the rivers actually lie below the plane of the present river banks, so that 'farming débris,' if any there be, must run up hill to enter the rivers. As to the few scattering farms in the foot-hills or on the mountains, their aggregate area is too insignificant to cut a figure in the case. Indeed, I have failed to discover any material wash in any of them, and I have seen them nearly all in the course of my explorations. The same may be said of the washings from wagon roads. One of your informants says, 'the cutting of wagon roads along mountain sides is a fruitful source of sediment, large masses of earth being washed down from them during winter rains.' Now I have travelled hundreds of miles over these mountain roads, and have observed them closely, but have found no slides or washing worthy of mention. It is evident that if the roads were subject to slides to any extent they would soon become impassable, while in point of fact they are almost without exception in a very fair condition. Any tendency to slides or washings is promptly checked by the owners if they are toll-roads, or by the authorities if county roads.

"Now, as to the present condition of the Yuba and its hydraulic mines, it is estimated that during the dry season 17,000 miners' 'inches' of water are used daily by the hydraulic mines of the Yuba, and that each miners' 'inch' removes at least 3 yd. of material in 24 hours. This gives a daily total of 51,000 cub. yd. Fully one-half of this is held in suspension by the running waters, and carried down the river in the shape of muddy water, or, more correctly speaking, liquid mud, and is deposited, as before stated, partly on the bottom lands of the Yuba, and partly into the rivers and bays beyond. That is to say—and I wish to emphasise this fact—25,000 cub. yd. of earth and sand, say 43,750 tons, are daily poured from the mountains into the valleys by the hydraulic mines. To use a familiar illustration, suppose it were required to transport that amount on railroad cars, it would take 110 trains of 40 cars each (one train every 13 minutes) to accomplish the daily task. In the rainy season, more water is used, and correspondingly more material is sent down; moreover, the winter freshets invariably clean out the cañons, and sweep away the heavier material that has accumulated at the mining dumps during the low stages of the river. The lighter material runs down with the stream, the heavier material rolls along the bottom with varying velocities, depending on the height and volume of the freshets, and in due course of time finds its way to the level reaches of the river in the foot-hills and the valley."

CHAPTER VI.

AURIFEROUS VEINSTUFF.

THE occurrence of gold in mineral veins and lodes has already been discussed from its geological and mineralogical standpoints (see Chapter II.). It remains to consider here some peculiarities in the veins, which nave a bearing upon the mode of mining, as well as the whole subject of the nature of the association between the gold and its matrix, and the means adapted for extracting it from that matrix.

Sections of Veins.—There would appear to be no actual limit to the variety of forms exhibited by auriferous veins of quartz and other minerals, and it would require a large volume to describe even a portion of the variations met with in any one mining district. It must suffice to illustrate some few of the most remarkable examples, which may be done within a convenient space.

FIG. 119.

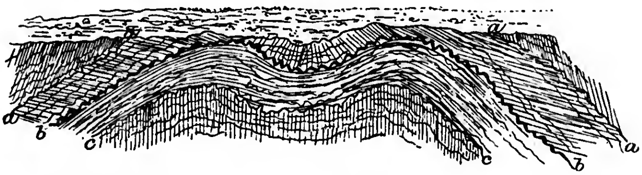


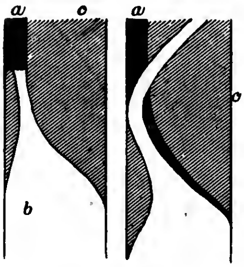
FIG. 120.

CONTORTED VEINS IN THE CARIBOU DISTRICT.

Fig. 119 shows a contorted vein worked in the Caribou district of Nova Scotia. It consists of an anticlinal fold having a subordinate synclinal fold at the apex. The dip of the axis of the anticlinal is E. The gold is followed by stopes, and the quartz removed by a process of long wall. The yield is about 4 oz. of gold per ton. The veins *a c* are about $\frac{1}{8}$ to $\frac{3}{4}$ in. thick; *b* varies from $\frac{1}{2}$ in. to 4 in. The country-rock is a soft slate, in places a sandy shale; the slate underlying *b* is auriferous in patches. Fig. 120 illustrates more clearly the curious contortions of the vein *b*.

Daintree says of the reefs of the Cape river district, Queensland, that they are situated on a flat at the foot of a high ridge, which follows the course of an elvan dyke of quartziferous porphyry. Branch veins from this intrusive mass have been injected into the surrounding slates, and it would almost seem that, in some cases, the rich quartz veins were a continuation to the surface of the elvan veins themselves. Sections (Fig. 121) taken in one of the shafts in the reef appear to warrant this assertion: *a*, reef; *b*, elvan dyke; *c*, slates.

FIG. 121.



ELVAN DYKES.

FIG. 122.

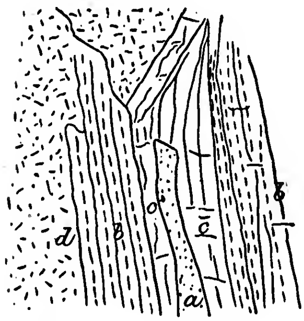


FIG. 124.

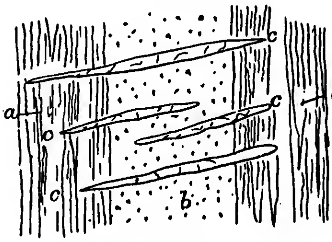


FIG. 125.

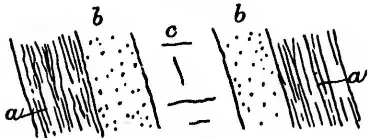


FIG. 126.

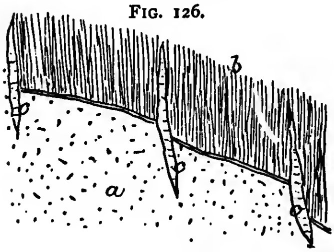
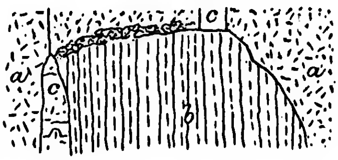


FIG. 123.



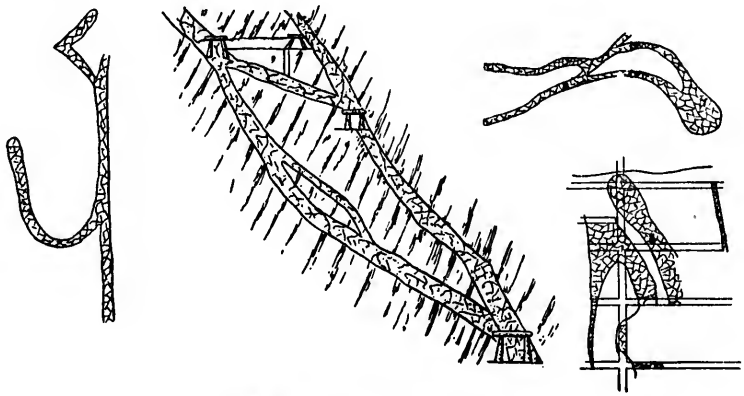
QUARTZ VEINS IN DIORITES AND GRANITES.

Figs. 122 to 126 illustrate the occurrences of quartz veins in the diorites and granites, and their contact zones, at Swift's Creek, Victoria.

In Fig. 122, *a* is a horse of silicious felsitic rock, containing much ordinary and arsenical pyrites; *b*, finely crystalline foliated contact-rock, with a little pyrites, and very micaceous in places; *c*, white translucent vein-quartz, about 8 in. wide with arsenical pyrites, yielding about 1 oz. per ton; *d*, quartz-diorite. In Fig. 123, *a* is coarse gneissic quartz-diorite, very much decomposed; *b*, schistose hornfels; *c*, auriferous quartz vein, 4 in. wide. In Fig. 124, *a* is Silurian (? Upper) mudstones; *b*, granitic dyke; *c*, auriferous quartz veins. The veins pass through the dyke and penetrate the sedimentary rocks on each side; the dyke varies in width from a few ft. to 200 ft., and is almost completely decomposed. In Fig. 125, *a* is Silurian (? Upper) slates; *b*, dyke; *c*, auriferous quartz veins. The dyke is a compact or fine-grained diorite of an almost felsitic character, and is highly mineralized by arsenical and iron-pyrites. In Fig. 126, *a* is the intrusive dioritic mass; *b*, Silurian sedimentary rocks (contact schists); *c*, auriferous quartz veins; *d*, plane of contact.

Fig. 127 shows a few actual sections of veins in the Clunes district, Victoria.

FIG. 127.



SECTIONS OF VEINS AT CLUNES.

The Sandhurst gold-field, Victoria, is remarkable for the regular saddle formation of its quartz reefs. In the North Garden Gully United Co.'s main shaft, they underlie each other as shown in Fig. 128. They are curiously faulted by an intrusive "lava" (composed of dense crystalline basaltic rock) dyke, which follows irregularly along the strike of the veins, and intersects them at various depths. The reference letters indicate: *a*, caps of reefs; *b*, "lava" dykes; *c*, saddle reefs; *d*, west leg of reef; *e*, Silurian strata. This mine has in 9 years paid over 600,000*l*.

in dividends, and the market value is about 200,000*l.* It is closely resembled by the Great Extended Hustlers, which, in 8 years, paid 560,000*l.* in dividends. The shaft has reached over 1400 ft. in depth without finding any productive reef below 733 ft.

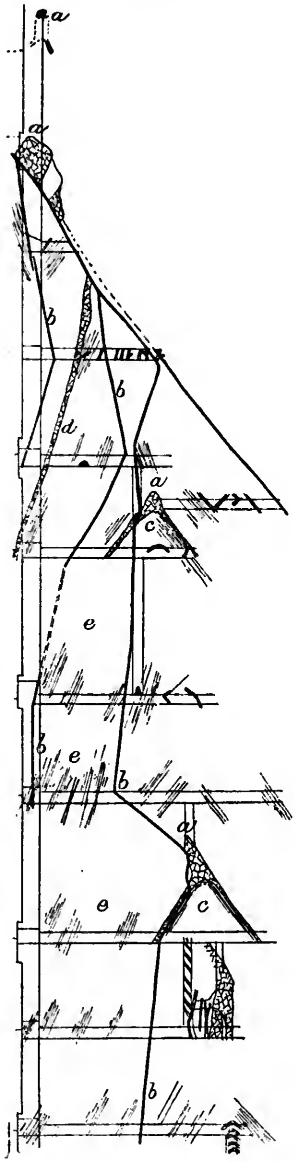
TREATMENT OF THE VEINSTUFF.

Gold occurs in its matrix (the veinstuff) in a finely divided state and distributed in irregular proportions, both in a "free" condition (i.e. not associated with other metals or metallic salts), and in combination (of a most intimate mechanical nature, but probably not chemical) with other metals or their ores. The first step in effecting the extraction of the gold from the veinstuff is to bring about its disengagement from its associated mineral matters, firstly, by mechanical means, or disintegrating the mass to such a degree of fineness as will enable the gold and other metallic bodies to be liberated from the un-metalliferous ingredients; and secondly, by processes which will be described in the next chapter, separating the gold from any base metal or ore accompanying it. The former operation, here to be discussed, is termed "milling" in America, and is conducted in an establishment generally known as a reduction works.

Crushing.—The work accomplished by the "stamps" is much facilitated and increased by subjecting the mineral as it comes from the mine (commonly called "stone," "rock," or "ore") to the action of a crusher, by which it is reduced to a more convenient size for feeding into the "stamps." Crushers are of many forms. Besides the well-known Blake crusher, made by H. R. Marsden of Leeds, and by the Blake Crusher Co. of New Haven, Conn., now too familiar to need any description, the following may be enumerated :—the Alden, made by Copeland, Dodge & Co., 206, Broadway, New York; Beckett & McDowell's, 5, Cortlandt St., New York; Colman's, made by Morey & Sperry, 92, Liberty St., New York; Dodge's, made by A. & F. Brown, 57, Lewis St., New York; Forster's, made by Totten & Co., 24th St., Pittsburg, Pa.; Hall's, made by the Savile Street Foundry Co., Sheffield; and Phelps', made by Copeland & Bacon, 85, Liberty St., New York. One deserving special mention is that made by the Sandycroft Foundry Co., near Chester, which presents unusual facilities for transport and erection, and is credited with high working capacity.

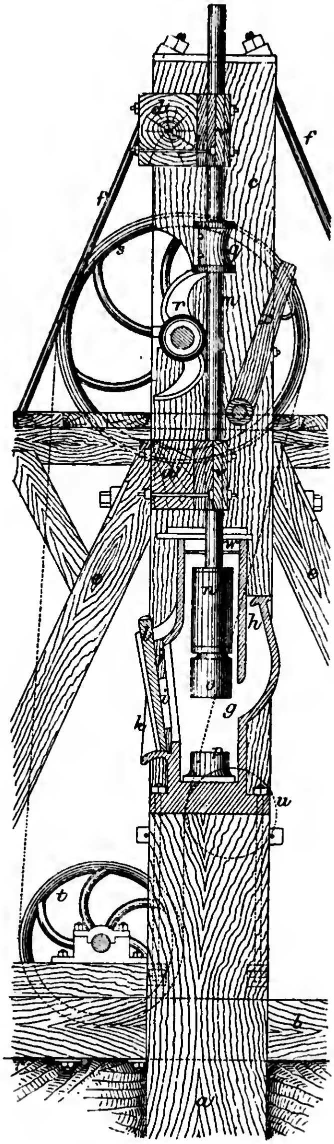
STAMPING.—The further comminution of the mineral is performed by "batteries" or "sets" (any number up to 6, but usually 5) of "stamps," which are heavy iron pestles, lifted to a height of some inches (say 7 to 15 in.), and allowed to fall upon the matter intended to be powdered. They work in a "mortar" or "coffer," an iron trough, constantly and regularly supplied with ore and water, and from which the

Fig. 128.



Saddle Reefs.

Fig. 129.



Construction of Battery.

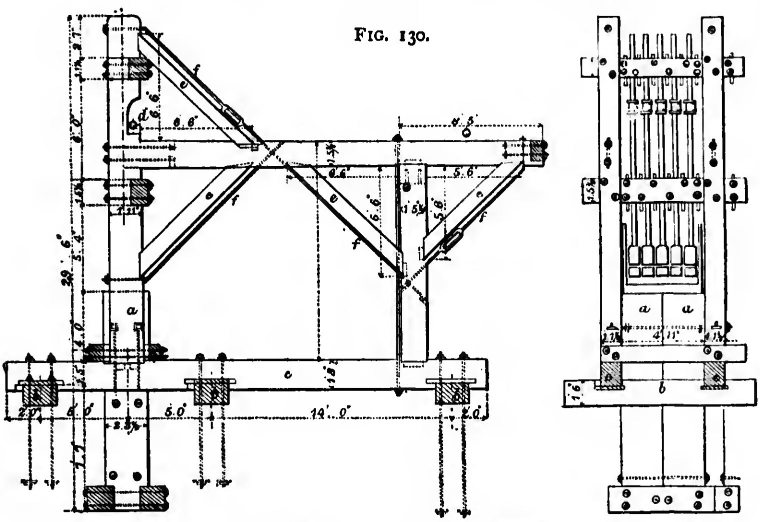
crushed material escapes, as soon as it is reduced to the desired degree of fineness, in the form of a liquid mud or "pulp," through the meshes of "screens" or "gratings" closely fitted in the sides of the "mortar." This latter is generally of rectangular form, resting on a solid foundation, and established in a substantial timber framework. The stamps are successively lifted at regular intervals by means of revolving "cams" or "wipers," arms of iron keyed to a cam-shaft, placed directly in front of the battery, and receiving its motion from the driving-power of the mill. The stamps move vertically between guides that form part of the battery-frame. The general construction of the several parts of the battery is shown in Fig. 129 (scale $\frac{3}{8}$ in. = 1 ft.) :—*a*, foundation-timber or mortar-block; *b*, transverse sill; *c*, battery-posts; *d*, tie-timbers; *e*, braces; *f*, tie-rods; *g*, mortar; *h*, feed-aperture: *i*, screen or grating; *j*, screen-frame; *k*, lugs to secure frame; *l*, wedge or key; *m*, stamp-stem or lifter; *n*, stamp-head; *o*, shoe; *p*, die; *q*, tappet; *r*, cam; *s*, pulley on cam-shaft; *t*, driving-pulley; *u*, tightener; *v*, guides; *w*, battery-covers; *x*, prop for supporting stamp when not at work.

Foundations.—The foundation-timber or mortar-block for batteries of this character often consists of heavy vertical timbers, placed close together, and firmly connected by cross-timbers and iron bolts. The timbers may be 6 to 12 ft. long, according to the nature of the ground and the proposed height of discharge from the mortar. Sometimes the timbers are laid horizontally, so as to serve as the base of two or more batteries. When the foundation-timbers are in place, the space about them is packed and stamped as firmly as possible with clay or earth. When the ground on which the batteries are to be built is a hard compact gravel, or a firm clayey material, the surface is sometimes levelled off so as to admit of laying the transverse sill-timber *b* of the battery-frame, and a narrow pit is then excavated, some 6 to 14 ft. deep, and long and wide enough to receive the ends of the mortar-blocks; the posts or blocks are introduced into the pit in a vertical position, their bottom ends resting directly on the ground without any intervening horizontal timber. The remaining space in the pit is then compactly filled with clay, which is pounded or stamped firmly into place. The sill-timbers *b* and battery-posts *c* are securely bolted to the foundation-timbers. The posts *c* are braced by the timbers *e* and rods *f*, and are connected by the tie-timbers *d*, which also support guides *v*.

It must ever be borne in mind that the foundations are of prime consequence. When improperly constructed, the battery cannot be run at its full speed and capacity, without shaking itself to pieces, whereby great delay, expense, and actual loss of metal are sure to arise. Extra care in securing complete solidity for the battery in the first instance will be amply repaid, while nothing will compensate for a rickety structure. Often it is advisable to excavate the foundations down to the solid rock, where that is not more than 14 ft. below the surface. At some mills, the trench itself is cut in the solid bed-rock, leaving about 2 ft. all round for packing.

Fig. 130 shows the details of the foundations and framing in greater detail. The mortar-blocks *a* are 30 in. square, and 12 to 14 ft. long. They are made quite true, and thoroughly coated with Stockholm tar, applied hot, then bolted together by 6 1½-in. pins and nuts. The transverse sills or foot-timbers are 18 in. square, 6 ft. long, and are let 6 in. into the mortar-block, freely tarred, and bolted together by 6 1⅛-in.

FIG. 130.



DETAILS OF FOUNDATIONS AND FRAMES.

pins after being squared. At 5 ft. from the top, the mortar-blocks are cut to 59 in. by 29 in. The prepared blocks are let down upon the floor, and levelled up by putting sand beneath. When in place, the height is accurately determined, and a level run across the whole set. The tops are planed smooth and dished about $\frac{1}{16}$ in., to prevent the surface becoming rounded; they are kept covered till the mortar is fixed on the top.

Frames.—In America, battery-frames are usually made of the best red spruce (*Abies rubra*) or sugar-pine (*Pinus Lambertiana*). First, 3 battery-sills *b* (Fig. 130), 18 in. by 24 in., and 28 ft. long, are placed parallel to the direction of the cam-shaft, one being 5 ft. from centre to centre behind the mortar-block, a second 5 ft. in front, and the third

14 ft. from the second. They are secured by bolts 8 ft. long, keyed into the masonry or to the bed-rock. In the latter case, holes 3 ft. deep and $1\frac{1}{2}$ in. diameter are bored in the rock; the bolts are slotted at 6 in. from the lower end, and wrought-iron wedges, $\frac{5}{8}$ in. by 1 in., 5 in. long, with a head 1 in. square, are made to fit the slots; the bolts are inserted in the holes, and driven so that the wedges enter up to their heads, when the holes are filled up with molten brimstone. Cast-iron washers and nuts retain the bolts in the sills. Next, the outside-line timbers *c*, measuring 20 in. by 14 in., and 28 ft. long, are wedged into the battery-sills, and secured by bolts. The top of the sill should be 4 ft. above the top of the mortar-block. The centre-line timbers measure 20 in. square and 28 ft. long. The intermediate-line timbers measure 20 in. by 14 in. by 28 ft., and are dressed on the upper side and reduced to $13\frac{1}{2}$ in. and $19\frac{1}{2}$ in. where they pass the battery-blocks; they are let 3 in. into the sills, and are secured by keys driven both ways and by 2 iron bolts 33 in. by $1\frac{1}{8}$ in. The outside battery-post measures 23 in. by $13\frac{1}{2}$ in., and is tarred and let into the sills. The posts for as many as 4 batteries may be raised simultaneously. The middle one is usually of somewhat larger scantling, say 23 in. by $19\frac{1}{2}$ in. The posts are secured to the line-timbers by 2 1-in. joint-bolts, 44 in. long. In the upper part of the posts is cut the cam-shaft journal-seat *d*. The posts are held together by the tie-timbers *d* (Fig. 129), carrying the stamp-guides *v*. The bracing and tie-bars *e f* are all arranged to ensure the greatest possible steadiness during work. A travelling block and tackle suspended over the battery will be found very useful for inserting and removing the stamps.

Mortars.—Mortars are now often fixed directly upon vertical mortar-blocks, without any horizontal sill intervening. When the frame is ready, the temporary covering is removed from the mortar-block, and the holes for the mortar-rods are bored from the template taken from the bottom of the mortar. All cracks in the block are filled up with molten brimstone, and its surface is again planed and tarred. In the Western States of America, it is a favourite custom, before fixing the mortar, to cover the top of the block with a triple thickness of common domestic blanket, thoroughly tarred on both sides. Upon this cushion, the mortar is bolted with $1\frac{1}{2}$-in. pins *d* (Fig. 131). This plan reduces the "jar" to a minimum, and prevents the gradual loosening of the mortar from the block, and consequent introduction of material into the space, whereby the perfect level of the mortar is destroyed.

Mortars may be constructed partly of wood and partly of iron—the sides and ends being of wood, and the bed-plate of solid iron—or they may be entirely of iron. The latter plan is now general, as with the compound method there is great trouble in keeping tight joints. The form commonly adopted is an iron box or trough, 4 or 5 ft. long and deep, and 12 in. wide inside, preferably cast in one piece, but sometimes made in sections bolting together, where transport is difficult. The bottom is always made very thick, as it has to bear the chief strain; but in positions remote from iron-foundries, it is an advantage to have the sides cast thin, and to attach a lining which can be renewed at will. This form of mortar is shown in Fig. 131. The feed-opening *a* is an aperture 3 or 4 in. wide, and nearly as long as the mortar, by means of which the ore, suitably

FIG. 131.

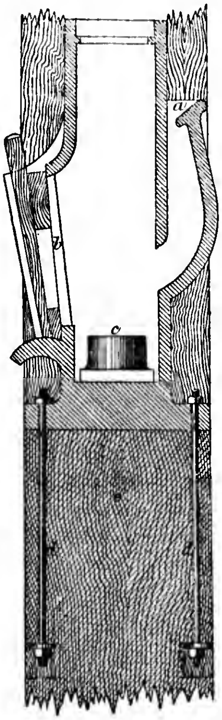


FIG. 132.

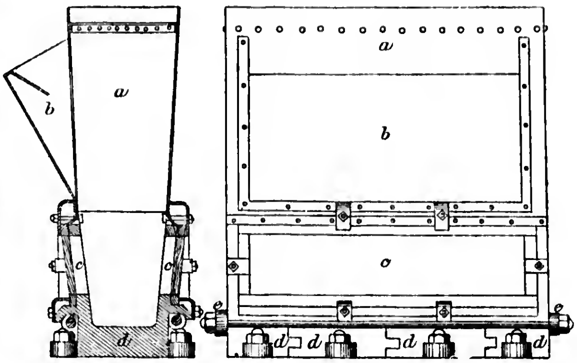
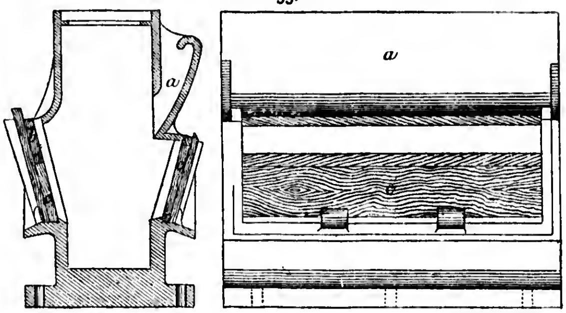


FIG. 133.



MORTARS OR COFFERS OF VARIOUS FORMS.

sized, is fed into the stamps. On the opposite side is the discharge, furnished with a screen *b*, by which the "pulped" material escapes; this opening is almost as long as the mortar, and 12 to 18 in. deep, the lower edge being 2 or 3 in. above the top of the die *c*. The bolts *d* hold the mortar on the block *e*.

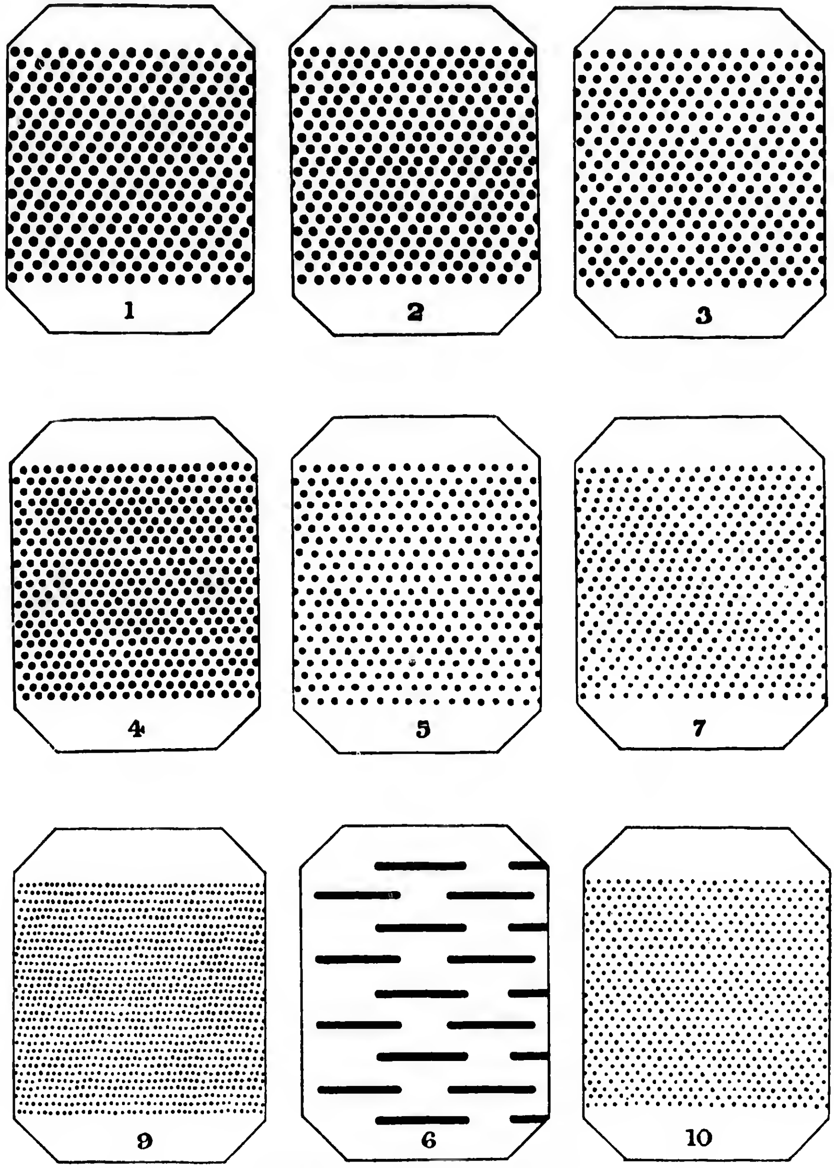
The Californian high mortar varies in weight from 3000 to 6000 lb.; it is usually about 4 ft. 7 in. long, 4 ft. 2 in. to 4 ft. 4 in. high, 12 in. wide inside where the dies are set, and 3 to 6 in. thick in the bottom. Mortars which are made in sections are termed "section-mortars." The one illustrated in Fig. 132 is 4 ft. long, and will take 5 stamps. The upper portions *a* are of boiler-plate, strengthened with angle-iron; the feed-opening is at *b*; there is a double discharge with screens at *c*, the screens being attached by movable lugs or clamps; the bottom is cast in 4 sections *d*, which are accurately fitted together with tongued and grooved joints, planed, and held by heavy iron bolts *e* running through them from end to end, and secured by strong nuts on the outside.

Donnell's mortar, much used in gold-ore crushing, is shown in Fig. 133. The ore is fed in at *a*, and the discharge is at back and front. The screen *b* is narrow, placed high above the dies, and occupies only a part of the opening in front. The lower portion of this opening, and the opening at the back, is closed by a wooden door *c*, covered on the inside by a sheet of amalgamated copper.

Screens.—The action of the stamps, when properly supplied with ore and water, results in the reduction of the solid matters to such a degree of fineness as will enable them to flow off with the water, which wells and splashes up, at each blow of the stamps, through the screens or gratings placed at the exit from the mortar. The position of the screens in the mortar has been already shown in Fig. 129. The screen should incline outwards at the top, to facilitate the passage of the pulp through its meshes. The length of the screens will vary with the length of the mortar, and the width is usually 10 to 15 in.

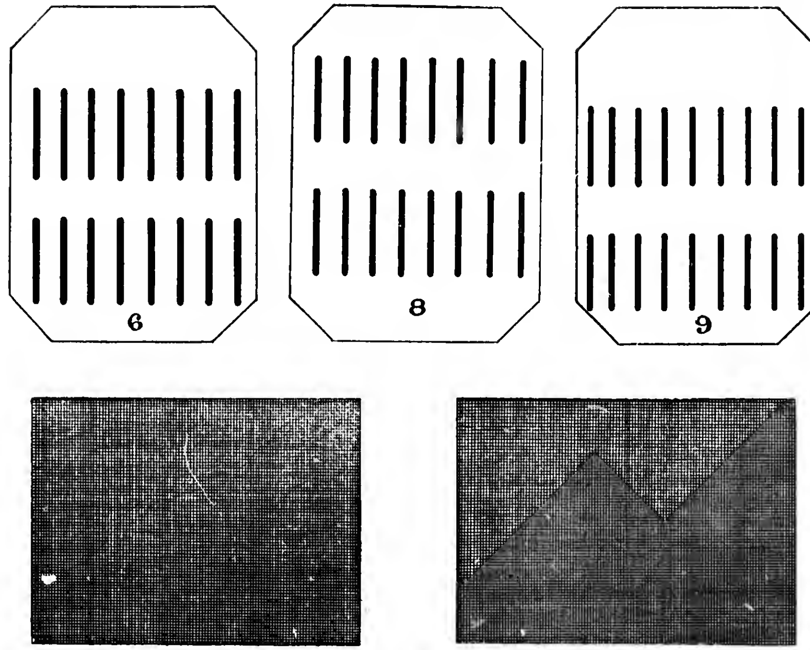
The shape, disposition, and size of the orifices in the screens are subject to the greatest possible variety. A few out of the many patterns in use are shown in Fig. 134, drawn from actual samples kindly lent for the purpose by John Patterson, Esq. The "gauge," or number of orifices per sq. in., adopted in Victoria ranges between 60 and 800; in America, it runs from 900 to 10,000. When the holes are round, their size is graduated by the numbers of sewing-machine needles, from 0 to 10: thus No. 5 is about $\frac{1}{16}$ in. diameter, and No. 8 about $\frac{1}{64}$ in. When the holes are slots, they are usually $\frac{3}{8}$ in. long and of the same diameter as a No. 6 needle. As regards material used in the construction of screens, Americans are universally in favour of Russia sheet iron or sheet steel, $\frac{1}{32}$ in. thick, weighing about 1 lb. per sq. ft., very soft and tough, with a clean smooth surface, and perfect freedom from rust or flaws; in Australia, sheet copper is often employed, that at the Port Phillip works being $\frac{1}{16}$ in. thick, with 84 holes per in. The holes should always be punched. This operation leaves one side in a rough state, like the outside of a nutmeg-grater. The rough side is turned inwards, towards the wear of the issuing pulp; and, as the inner end of the orifice is smaller than the outer, there can be no fear of the meshes becoming clogged, as

Fig. 134.



Screens or Gratings (actual size).

FIG. 134—*continued.*



SCREENS OR GRATINGS (actual size).

everything which enters from the inside can more readily escape on the outside. A 5-stamp battery usually requires 13 sets of screens per annum, a set consisting of 5 sheets of 1 to 1½ sq. ft.

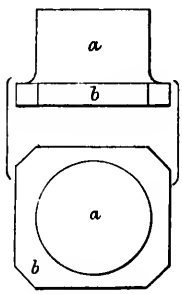
The "stamp duty" or effective capacity of a battery is governed entirely by the facility with which the pulp can escape. It is therefore obvious that proper adjustment and gauge of the screens are most important matters. The object sought is to reduce the mineral just sufficiently to enable the gold to free itself from the gangue, and to thus reduce the greatest possible quantity in a given time. Microscopical examination of the ore and of the pulp will afford some guide in this respect, as will also the same test applied to the tailings escaping from the mill. It is hardly necessary to point out that the rate of discharge will also be proportionate to the area of screen presented to the pulp, whence it follows that the screens should be as deep and wide as possible. The most rapid delivery would be attained by having a single stamp surrounded by screen on all sides; and every battery should at any rate have a back and front delivery. Where the feed is on one side and the discharge on the other, the working power of the battery is reduced by one-half. The importance of this is apparently not yet recognized by some engineers. Experiments have shown that pulp fed back into the mortar takes nearly as long to escape through the screens as rock which has first to be reduced to pulp. Fine stamping does not necessitate the use of fine-gauged screens, as the same result may be gained by elevating the screen, though with a certain loss of effective capacity.

Dies.—In order to save the mortars from wear and tear, "dies" or "false bottoms" are placed in them, to receive the blows from the stamps. In America, the die is a cylindrical piece of cast iron, corresponding in form to the shoe of the stamp that falls upon it, and 4 to 6 in. high. Some mortars are made with circular recesses in the bottom, for the dies to fit into. In others, to prevent the material from working in under the die and displacing it, the circular recess in the bed-plate is cast with a flange, and the die with a small projection or lug. A groove is also made in the bottom of the mortar, so that the die may be introduced, with its lugs dropping into the groove; the die being then turned about 90°, the lugs come under the flanges of the recess, and the die is thus held in place. A simpler and more general plan is to cast the die with an upper circular "boss" or die proper *a*, on a square flat "foot-plate" *b* (Fig. 135). The bottom of the mortar is then also made flat, and the dies are dropped in, resting on their foot-plates, which just fill up the space in the floor of the mortar. The corners of the foot-plates of the dies are bevelled off, so as to allow of the insertion of a pick for effecting their removal when necessary. The foot-plate of American dies is usually 1½ to 2 in. thick and 10 to 12 in. square; the boss is 3 to 5½ in. high and 8 to 10 in. in diameter. It is of hard tough cast iron, and is chilled down to the foot-plate. In Victoria, it is found to be a good plan to allow the dies to rest immediately upon a layer of finely-broken quartz, at least 3 in. deep, by which means an opportunity is provided for the liberated gold particles to get into the gravel, out of reach of the stamps, and whence they can readily be recovered. In some localities, the die consists of a simple slab of iron filling the whole mortar, and which is turned over when one side is much worn; but the wear is liable to be uneven, and the die often breaks before it is worn out.

Stamps.—The stamp consists of a stem or lifter; a head or socket attached to the lower end of the stem, and furnished with a shoe, a movable part which sustains the force of the blows and the wear of the operation; and the collar or tappet, by means of which the revolving cam lifts the stamp for its fall. The stem is a round bar of wrought iron, about 3 in. in diameter, usually turned in a lathe. Its length is 10 or 12 ft. Its lower end is slightly tapered, and corresponds in form to a socket or conical hole in the upper part of the stamp-head. The rest of the stem is usually made round throughout its entire length, the method, now in general use, of attaching the tappets to the stems not requiring any modification in the form of the latter, as was formerly the case.

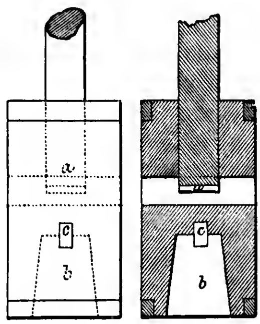
The stamp-head, illustrated in Fig. 136, is a cylindrical piece of tough cast iron, about 8 in. in diameter and 15 in. high. In its upper end is a socket, shown by dotted lines, corresponding with the axis of the cylinder, and conical in form, designed to receive the slightly tapering end of the stem, to the dimensions of which it must be adapted. This conical hole or socket is about 7 in. deep. At its bottom is a hole or key-way *a*, passing through the head at right angles to the cylindrical axis, by which passage a key may be driven in to force the head from the stem when necessary.

Fig. 135.



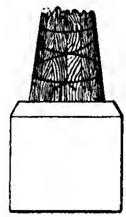
Die.

Fig. 136.



Stamp-head.

Fig. 137.



Shoe-fastening.

To attach the stamp-head to the stem, the latter is placed in its position between its guides, the head standing immediately under it. The stem, being dropped, enters the socket, and a few blows of the hammer drive it in with sufficient force to cause the head to be raised when the stem is lifted. The stem and the head, being suffered to drop together a few times, become firmly connected. In the lower end of the head is a similar hole or socket *b*, but larger than the upper one, likewise tapering or conical in form, made to receive the stem or shank of the shoe, which is thus connected with the head in a similar manner; a rectangular hole or passage *c* through the head at the end of this lower socket, permits the removal of the shoe in the same way as the stamp-stem is forced out from the upper socket. A stout wrought-iron hoop encircles each end of the stamp-head, being fitted and driven on when hot, and allowed to shrink in place.

The shoe in common use is a cylindrical piece of cast iron about 8 in. in diameter and 6 in. high, above which is a shank or stem, the base of which is 4 or 5 in. in diameter, tapering in form, and about 5 in. high. It is made of the hardest white iron. It is attached to the head in manner somewhat similar to that just described for connecting the head and the stem, but is wedged on by means of strips of pine-wood. These strips, which are cut about as long as the stem of the shoe, $\frac{1}{4}$ in. thick and $\frac{1}{2}$ in. wide, are placed around the stem of the shoe, and tied with twine, as shown in Fig. 137. They must be thick enough to wedge the stem of the shoe firmly in its socket, without allowing the head to come into contact with the body of the shoe. When the shoe is ready to be fixed to the head, it is placed in proper position, with the stem of the shoe directly under the socket of the head, and the stamp and head are then allowed to drop upon it. If necessary, a few blows of a hammer are struck upon the top of the stamp-stem. The whole may then be raised, the shoe keeping its place, and suffered to fall repeatedly, until the shoe is firmly established in its socket. During this operation, a piece of plank is interposed between the die and the shoe, for the latter to strike upon. When a shoe is worn out, it can be removed from the socket by driving the key into the key-way *c*, and forcing it off. Care must be taken that the shoe does not become so thin as to permit the head to sustain undue wear, and so become weakened. Shoes should be renewed when worn down to a thickness of 1 in.

It was at one time objected that the effective capacity of round stamps was less than that of square ones; but it has been proved, by careful experiments under uniform conditions, that they are equal in this respect. At the same time, the circular stamp possesses a great advantage in that it can be caused to revolve on its own vertical axis while at work, making a partial revolution at each blow, the rotary motion being continued during the free fall of the stamp, which produces a grinding effect upon the material between the shoe and the die, increasing the effective duty of the stamp, and equalizing and reducing the wear of the shoe. Bland declares himself satisfied that the square heads used at the Port Phillip works are more efficient and economical, the cam-barrel being simpler and more easily kept in order. Round revolving stamps are almost a necessity when the feeding is done by hand from the back only; but with self-feeding all round the stamps, he considers the square head the better.

Weight of stamps.—This is subject to great variation. In Victoria, the figures usually range between 224 and 1232 lb. per head; in America, 700 to 950 lb. Generally a medium weight of 560 to 672 lb. best suits the character of the ore, but some ores are met with requiring the higher figures.

Height of drop.—The height of the drop or fall of the stamps varies from 2 to 11 in. in Victoria, and from 7 to 11 in. in America. It should not be less than 7 in., and may be increased with advantage if the stamps are light.

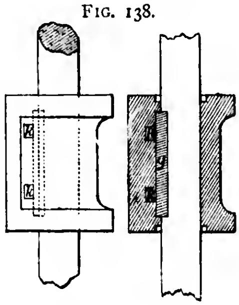
Speed.—The number of drops made by each stamp per minute is the "speed" of the battery. In Victoria, it varies from 45 to 85 blows, 75 to 80 being generally considered most effective; in America, 70 to 100.

Order of drop.—The order in which the stamps drop varies in different mills, but the desired conditions are (1) that the work of raising the stamps shall be uniformly distributed on the cam-shaft, so that the weight lifted shall be, as nearly as possible, the same at any period of the revolution; and (2) that each stamp shall fall effectively upon the material to be crushed, and maintain its proper distribution in the mortar. If all the stamps fell at the same time, the structure would soon be knocked to pieces; and if they fell in regular succession, from one end of the battery to the other, the material would accumulate at one end, and the effective duty of all the stamps would be greatly diminished. In a 5-stamp battery, the common sequence is 3, 5, 2, 4, 1, or, in other words: (1) the middle stamp, (2) the end one on the right, (3) the second on the left, (4) the second on the right, (5) the end one on the left. Another sequence, which makes a backward and forward wave, and thus keeps the mortar very evenly filled, is 3, 4, 5, 2, 1. Others which find favour are—3, 4, 2, 1, 5; 2, 4, 5, 3, 1; 3, 5, 1, 4, 2; 1, 5, 2, 4, 3; 1, 5, 4, 2, 3. It is thought that the middle stamp dropping first secures the greatest discharge, and that the end stamps dropping first effects the maximum of work done.

Character of blow.—The character of the blow delivered by the stamp upon the ore demands attention. The hardness of the mineral containing gold is almost always so much greater than that of the gold itself, or even of auriferous pyrites, that the same amount of stamping on the three substances will render the two latter much finer than the former. But it is of the utmost importance to prevent the gold being smashed too fine, or beaten flat, for in those conditions it is very difficult to save effectively. The tendency of slow heavy blows is to flatten the gold-particles, while that of smart light blows is to effect disintegration without materially altering the shape of the particles.

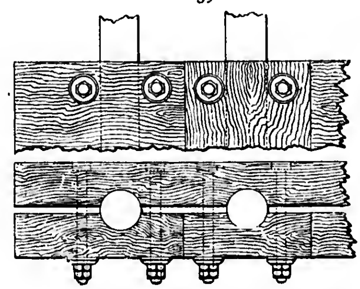
Tappets.—The collar or tappet is a projecting piece, firmly secured to the upper part of the stem of the stamp, by means of which the revolving cam may lift the stamp and let it fall upon the substance to be crushed. Tappets vary in form and method of attachment to the stem, but that which seems to combine the greatest number of advantages, and to have been most generally adopted on the Pacific coast, is that which is known as Wheeler's "gib-tappet." Fig. 138 shows an elevation and vertical section of this contrivance. It is a piece of cast iron, cylindrical in form, about 8 in. in height and diameter, and hollow at the centre, so as to receive the stamp-stem. To secure the tappet to the stem, there is a gib *g*, about 2 in. wide, and nearly as long as the tappet, having its inside face curved so as to correspond in form to the circular hole through which the stem passes. The gib being fixed in its place in the tappet, and the latter being upon the stem, it is pressed against the stem by means of two keys *k*, driven into the key-ways with force sufficient to hold the tappet and stem firmly together, and prevent slipping between them. This is found to be a very effective method of securing the tappet, while permitting it to be fixed at any desired point on the stem, according to the wear of the shoe. The stem is uniform in size, and the work of cutting facings, screw-threads and key-seats on the stem, required by other methods, is thus avoided. The revolving cam, meeting the tappet, and raising the stamp, causes it, while being lifted, to make a partial revolution about its vertical axis.

FIG. 138.



TAPPET OR COLLAR.

FIG. 139.



STAMP-GUIDES.

Guides.—The stamp is held vertically in its movement by guides, between which the stem passes. These were formerly made of iron, but such have been almost entirely replaced by wooden ones in Nevada and California. One set of guides is placed below the tappet, about 1 ft. above the top of the mortar; the other set is placed near the top of the stem, so that 6 in. or 1 ft. of the latter may project above the guides. They are supported by the cross-timbers or ties *d* (Fig. 129), which form a part of the battery-frame, connecting the two uprights or posts. They are usually made of pine, though hard wood is preferred, and are 10 to 16 in. wide. One part of the guide is made in a single piece for the whole battery, and bolted to the cross-timber; the other may be in one piece, like the first, or cut into as many pieces as there are stamps in the battery, as in Fig. 139, which are then secured to the corresponding part by bolts. In each part are cut semicircular recesses, which form, when the two parts are put together so that the recesses correspond, the holes or stem-ways for the reception of the stamp-stems. When the guides are so much worn by friction as to permit too much motion of the stems, they may be dressed down on their adjacent faces, by which means the recesses are reduced to nearly the proper dimensions.

Cams.—The cam is a curved arm fixed to a shaft, which is so placed in front of the battery that, by the revolution of the shaft, the cam is brought into contact with the tappet of the stamp-stem, causing the tappet to rise to a height determined by the length of the cam, and to fall at the moment of its release from such contact.

In Nevada, the cams are made of tough cast iron, and are usually "double-armed," that is, have two arms attached to one central hub. Fig. 140 shows the form of cam generally in use: *a* is the hub; *b*, the arms; *c*, the face; *d*, a strengthening rib.

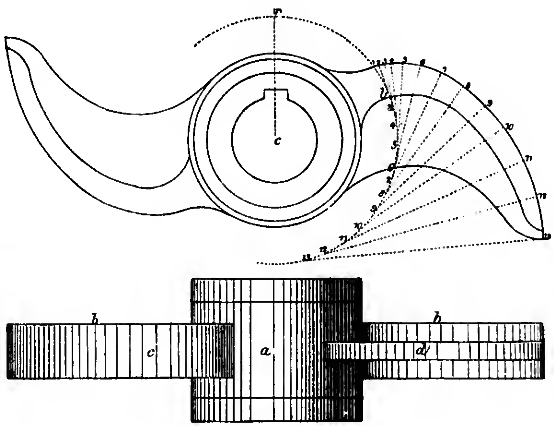
The proper curve of the face of the cam, in order that it may perform the required duty with the least friction, is the involute of a circle the radius of which is equal to the distance between the centre of the cam-shaft and the centre of the stamp-stem. This produces a line for the face of the cam which meets, better than any other, the various requirements. The bottom of the tappet is constantly perpendicular to the radius of the curve of the cam; the tappet, and with it the stamp, is lifted vertically and uniformly, so that the lift of the stamp is always regularly proportioned to the revolution of the cam-shaft.

The cam-curve may be constructed on paper by means of tangents, as shown in Fig. 140. If *c* represents the centre of the cam-shaft, and *c r* the distance from the centre of the cam-shaft to the centre of the stamp-stem, the circle described about *c*, with *c r* as a radius, is the developing circle of the involute. The distance, representing the height to which the stamp is to be lifted, is laid off upon the circumference of this circle, as from the point 1, which distance is subdivided into a convenient number of equal parts, determining, as in Fig. 140, the points 2, 3, 4, to 13. From each one of these points in the circle, a tangent is drawn, on which is laid off a distance equal to the length of arc between the point 1 and the point from which the tangent is drawn. All the points thus determined in the tangent lines are points in the cam-curve, and may be connected as shown in the figure, thus producing the line for the face of the cam.

In practice, the line of curvature is produced by cutting from a thin board a circular piece, the radius of which is equal to the horizontal distance from the centre of the cam-shaft to the centre of the stamp-stem. At a given point on the periphery of the circular piece is fixed one end of a thread, which must have the length of the greatest desired lift of the stamp, and to the other end of which is attached a pencil-point.

The circular piece, with the attached thread wound on the periphery of the circle, is laid on a smooth board, on which the line is to be traced, and the thread being constantly stretched to its farthest reach, is unwound until it forms a tangent to the circle at the point where the other end is attached. The line described by the pencil-point is the desired curve.

FIG. 140.



CAM OR WIPER.

Some builders slightly modify this curve, giving to the cam-arm a greater curvature near each of its ends, in order that the cam in its revolution may come into contact with the tappet at the least practicable distance from the cam-shaft, where the concussion is less than at a greater distance, and to diminish the friction between the extreme end of the cam and the face of the tappet. The face of the cam is 2 or $2\frac{1}{2}$ in. wide. Its extreme end is fashioned so as to correspond to the outer edge of the tappet, which is circular. The cam is placed as near the stamp-stem as practicable without coming into contact with it. The cams are caused to revolve by means of the cam-shaft, to which they are secured by one or sometimes two keys or wedges.

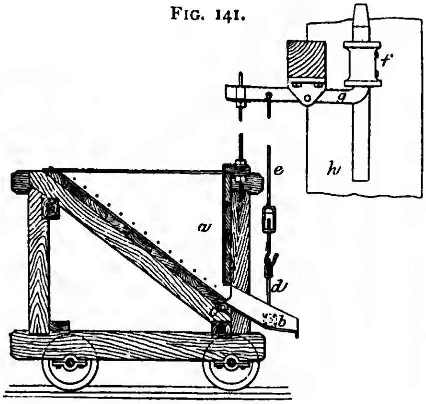
Cam-shaft.—The cam-shaft is a round shaft of iron, which is smoothly turned and finished, having one or two key-seats or grooves cut in it lengthwise, for the purpose of securing the cams in their places. The shaft rests in boxes, which are usually supported by shoulders cut on the upright posts of the battery-frame. Cam-shafts vary in diameter from 4 to 6 or 7 in., according to the number of cams to be fixed upon them, and the weight of the stamps to be raised. In some mills, a single cam-shaft is made long enough to carry all the cams for as many batteries as there may be. In Nevada and California, however, short cam-shafts are in general use, a separate shaft being employed for each battery, or, in many cases, one shaft for two batteries. Separate cam-shafts are preferred, on account of the independence of each battery, so that if one be stopped by any accident to the cams or stamps, or for repairs of any kind, the operation of the others is uninterrupted. Each shaft in such case is driven by its proper pulley, which receives its motion by means of belting from a counter-shaft. The order in which the stamps are to fall being determined, it is carried into effect by fixing the cams on the shaft in such position that each cam, by the revolution of the shaft, will lift its respective stamp at the desired moment. For this purpose, the key-seats cut in the hub of the cam must be determined with care; one common key-seat being cut on the cam-shaft, when the desired position of any given cam has been ascertained, the key-seat in the hub is cut to correspond with that of the shaft.

Props.—When it becomes necessary to hang up a stamp so that the cam may revolve without reaching the tappet, it is supported by a prop or stud *x* (Fig. 129). The lower end of the stud, of which there is one for each stamp, is pivoted on a small shaft fixed across the battery from end to end, resting in boxes, which are secured to the uprights. Each stud is just long enough to support the stamp, when placed under the tappet, at a height which is about 1 in. above the highest lift given by the cam. To bring the end of the stud into this position when desired, the workman lays a smooth stick on the face of the cam as it is rising to the tappet, and holds it there while the stamp is lifted. The stick is as wide as the face of the cam, and long enough to be held conveniently, and $1\frac{1}{2}$ in. thick at the end which comes between the cam and tappet. By this means the stamp is raised high enough for the stud to be put in place, which being done, the stamp is supported above the reach of the cam. To set it again in motion, the operation is repeated, the stud being withdrawn at the moment when the stick on the face of the cam has lifted the stamp clear of its support.

Feeding.—Much of the effectiveness of the stamps depends on the degree of care devoted to keeping the working parts in good condition, and on the regularity with which they are supplied with ore. This is commonly done by hand labour, the rock being shovelled in at such a rate as it is crushed and discharged. In some mills, however, automatic feeders are employed, which give satisfaction. These consist of a hopper filled with ore, from which a trough or chute leads to the feed-opening of the battery, so inclined that the ore will slide down from the hopper to the battery if the chute, which is hung on a pivot, be agitated. A rod is attached to the chute, and so placed that the tappet of the stamp, when the latter gets so low as to require an additional supply of rock, will strike its upper end, thus giving a shock which causes the ore to move down and fall into the battery. But a great objection to most automatic feeders is that they are arranged to supply one constant quantity, and make no difference in the work for the several parts of the mortar under varying conditions. With hand-feeding, the ore is received into a large bin or pocket, the floor of which is made in such a way that the ore will run easily towards the mortar. Here, in a space of 6 to 12 ft., stand the feeders, whose duty consists in keeping a constant amount (generally 2 in. deep) of ore between the shoes and dies, whereby the drop of the stamps is maintained at an equable height.

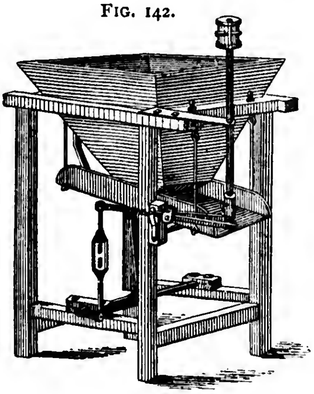
Automatic ore-feeders are broadly of one type, as just described. Stanford's feeder, as made by Joshua Hendy, 49, Fremont St., San Francisco, is shown in Fig. 141. It consists of a hopper *a* with adjustable spout *b*, swung on trunnions *c*, and attached to a cross-bar *d*, suspended from an adjustable rod *e*. A feeding-tappet *f* is keyed upon the battery-post *h*, and a lever *g* rotating on pivots is fixed to the rod *e* so as to be

FIG. 141.



STANFORD'S ORE-FEEDER.

FIG. 142.



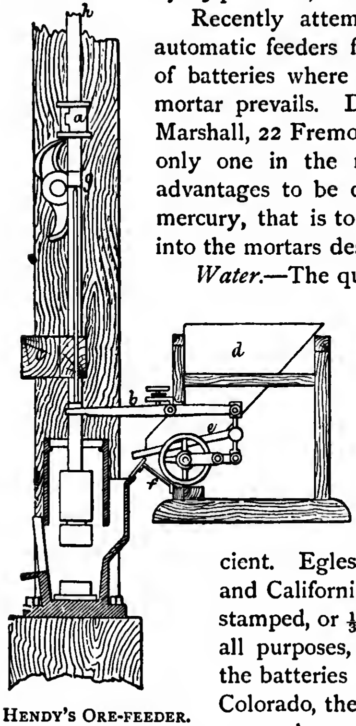
TULLOCH'S ORE-FEEDER.

struck by the cam-tappet, the lever *g* being forked that it may span the stem. While the battery is supplied with sufficient ore, the tappet does not descend far enough to strike the end of the feeding-rod; when the ore gets low, the tappet does strike the rod, and the effect is an oscillation of the front spout on its trunnions, whereby the ore is thrown forward. The apparatus being on wheels can be readily removed. It is simple in construction and operation, maintains the feed at any desired degree, and materially reduces the wear and tear of the stamps, while increasing their duty, it is said, 25 per cent. It seems best adapted for dry-crushing.

The Tulloch feeder, also made by Hendy, is likewise largely used. It is illustrated in Fig. 142.

Hendy's "Challenge" feeder is perhaps the most popular for wet, sticky ores. The mode of attaching it (to the second stamp in the battery) is shown in Fig. 143: *a*, tappet; *b*, lever; *c*, lower guide; *d*, hopper; *e*, carrier-table; *f*, shoot; *g*, bumper; *h*, stamp-stem. This feeder is said to effect a reduction of the wear and tear by 15 per cent., and an increase of duty by 20 per cent.

FIG. 143.



HENDY'S ORE-FEEDER.

Recently attempts have been made to introduce automatic feeders for supplying mercury to the mortars of batteries where the practice of having mercury in the mortar prevails. Dubois' apparatus, made by Whitney & Marshall, 22 Fremont St., San Francisco, seems to be the only one in the market. There are obviously many advantages to be derived from the automatic feeding of mercury, that is to say if the practice of putting mercury into the mortars deserves to be supported at all.

Water.—The quantity of water used in wet crushing depends in a great measure upon the character of the ore and the degree of fineness to which it is crushed. In Victoria, the proportion varies from 30 to 1200 gal. per stamp-head per hour, though 300 to 500 gal. would appear to satisfy all requirements. In America, about 93 gal. is commonly thought sufficient. Egleston says the consumption in Nevada and California is 200 to 300 cub. ft.* per ton of rock stamped, or $\frac{1}{3}$ to $\frac{1}{2}$ cub. ft. per stamp per minute, for all purposes, leaving probably about $\frac{1}{4}$ cub. ft. for the batteries alone (or nearly 94 gal. per hour). In Colorado, the amount is 28 cub. ft. per ton of rich ore, and 33 cub. ft. per ton of poor ore. The cub. ft. of ore averaging 108 to 125 lb., this will give $\frac{1}{4}$ cub. ft. per stamp per minute, or about the same as Nevada and California. When the water used is purchased from a "ditch company," it is measured by the miners' "inch" (see p. 953).

The water is fed to the stamps by horizontal piping just above the feed-slot of the mortar, with orifices opposite each stamp, capable of being closed if necessary; or the main feed may be brought higher up, and vertical supplies be carried from it down to each stamp, with valves at the ends. The main is often a 3-in. gas-pipe. A second main of half the size is placed in front, to help carry off the pulp. In America,

* 1 gal. = $277\frac{1}{4}$ cub. in.; 1728 cub. in. = 1 cub. ft.

arrangements are always made to heat the water supplied to the stamps, by waste steam or otherwise, during winter.

Tables of Dimensions and Duty.—The annexed tables reveal at a glance the dimensions and working results of a number of mills in various parts of the world, including some that may be considered representative.

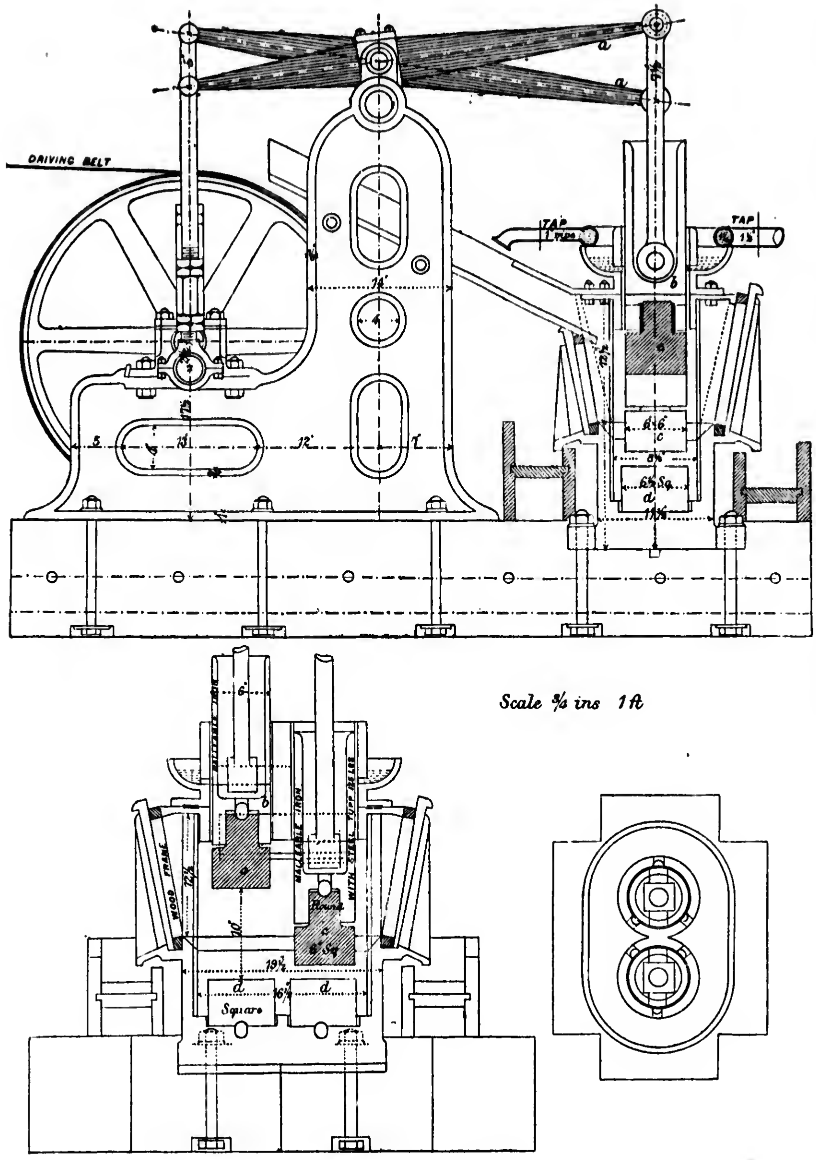
Mill or District.	Weight of stamps.	Drops per minute.	Depth of drop.	Crushed per 24 hours.	No. of stamps.	Duty per stamp.	H.P. per stamp.	Holes per sq. in. of grating.	Water per stamp per 24 hours.	Mercury used per stamp.	Mercury lost per stamp.
	lb.		in.	tons.		tons.			gal.	lb.	oz.
Grass Valley	850	61	10	40	20	2	..	..	..	..	..
,,	700	68	10	32	20	1·12	..	..	..	..	..
Eureka ..	950	80	9	..	60	2½–3	..	..	..	..	..
Brunswick .	..	..	..	160	56	3	..	..	..	..	..
Keystone ..	750	75–80	..	75–80	40	2	..	..	..	..	..
Idaho.. ..	950	80	9	..	..	..	..	..	..	..	..
Metacom ..	900	90	10	..	..	..	..	..	..	..	..
Port Phillip	672	75	..	..	56	2·2	1	..	..	..	..
,,	896	75	..	..	24	3	1¼	..	..	..	..
Nova Scotia	650	55	6–9	..	..	1–1½	..	..	..	..	..
	cwt.										
Ballarat ..	4–8½	50–85	7–10	..	..	1–4	1–2	40–200	950–8640	5–75	1–8
Beechworth	4½–7¾	40–90	5–14	..	..	⅘–4	¾–1½	60–140	720–11,520	5–70	½–8
Sandhurst ..	5–8	25–75	6–18	..	..	1–3¾	⅔–2	64–140	4000–8640	10–40	½–5½
Maryborough	4½–8	50–75	6–22	..	..	1–3	½–2½	70–144	900–8640	3–30	1¾–8
Castlemaine	4½–8	35–75	6–15	..	..	1–3¼	½–2	40–144	4800–12,960	6–40	¼–24
Ararat ..	5–6¾	60–72	7½–10	..	..	1¼–1½	¾	90–120	4320–12,960	6–47	½–7
Gippsland ..	6–7½	60–80	7–10	..	..	1½–2	¾–1½	70–250	1600–25,000	10–[illegible]	⅛–32

Name of Mill.	Length of stem.	Diam. of stem.	Weight of stem.	Height of shoe.	Diam. of shoe.	Weight of shoe.	Height of boss.	Diam. of boss.	Height of tappet.	Diam. of tappet.	Weight of tappet.	Height of die.	Diam. of die.	Weight of die.
	ft.	in.	lb.	in.	in.	lb.	in.	in.	in.	in.	lb.	in.	in.	lb.
Douglass	12½	2⅞	290	9	8	115	18	8	12	8	120	..	..	..
Cons. Virginia ..	13	3⅛	320	7	8	110	16	8	10	7½	95	..	..	..
Lincoln	13	3⅛	320	7	8½	119	18	8½	10	7¾	93	5½	8½	99
Brunswick ..	15	3⅛	375	10	9	125	18	8	12	9	125	..	..	..
Electric	11⅔	3	258	8	8⅛	123	16	8⅛	8½	7½	83	6	8⅛	100
Eureka	14	3½	450	..	..	160	..	..	..	..	120	..	..	120
Keystone	..	..	..	..	..	100	..	..	..	..	100	..	..	113
Stanford	..	..	..	..	..	120	..	..	..	..	114	..	..	..
Walhalla	10¾	3⅜	..	9	10	..	14	10	..	..	..	..	..	..

Special forms of Stamp.—Within recent years, several forms of stamp have been introduced which exhibit a departure from the ordinary rules governing the construction of batteries. They are based mainly upon one principle, which is to have at most 2 stamps in a battery, working at great speed (150 to 200 blows a minute), and weighing only 2 to 4 cwt. each. They thus present several advantages, among which may be specially mentioned (1) their lightness and consequent portability, (2) the rapid discharge effected by the all-round delivery, and (3) the sharpness of the blow. The principal forms will be described in alphabetic order.

Dunham's.—The chief feature of this stamper consists in the employ-

FIG. 144.

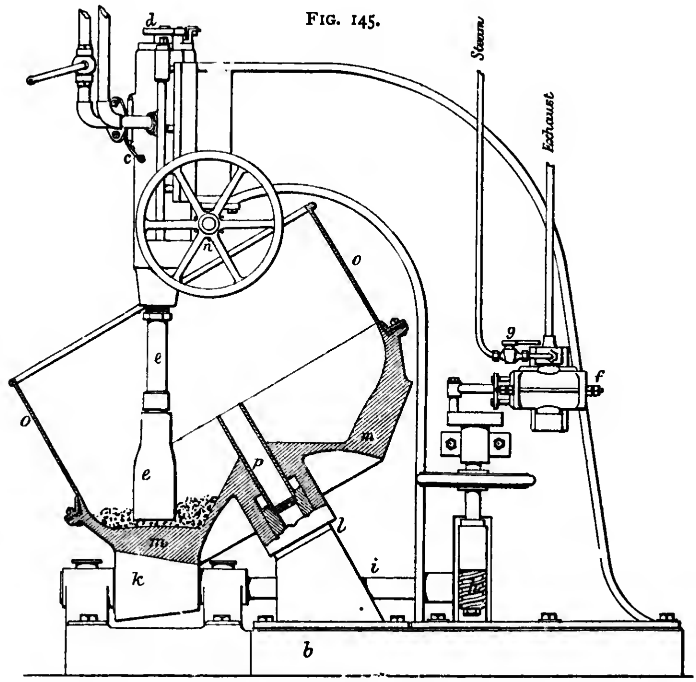


DUNHAM'S RECOIL STAMP.

ment of 2 plate-springs, balancing each other, mounted on bearings placed in rear of the centre of their length, and driven at the short ends by connecting-rods (whose length is adjusted to the wear of the shoes), driving-shaft, and pulley, in the usual manner. The machine is shown in Fig. 144, being of a size to crush 12 to 15 tons per 24 hours, at 250 blows a minute. Attached to the long arms of the springs *a* are suspended cast-steel tupps *b*, with forged and tempered steel shoes *c*, striking elastic blows on the material lying on the dies *d*. With some qualities of material, each head can deliver 300 blows a minute. A point in which this stamp excels all others is that the gratings are on each of the 4 sides of the battery. The total weight of the machine is 1⅝ ton, and the heaviest part is less than 3½ cwt. The same patentee has a much more portable machine for prospecting purposes, in which the heaviest part is less than 100 lb. The machine shown in the illustration is made by J. Copley & Cc., Middlesborough.

Fisher's.—Fisher's patent rotating-bed stamping mill differs essentially from the other forms dealt with in this section, and is shown in Fig. 145. It is the invention of John Fisher, 39A, Threadneedle St., E.C. The working parts are as follows:—a strong cast-iron frame is bolted to a substantial bed-plate *b*, and carrying at its upper end the cylinder *c*; in this is fitted a piston, which, by admitting steam or compressed air through the supply-pipe, as shown, is made to reciprocate up and down at a very high velocity, namely (according to the pressure used) from 400 to 800 strokes per minute. On the top of the piston is fixed a nut working on a rifled or twisted bar, which passes through the upper end of the cylinder, and is prolonged sufficiently far through the cover to admit of a ratchet-wheel, shown at *d*, being keyed to it, into which a pall is fitted in such a manner as to allow of the stamp-head *e* revolving on its descent only, viz. when coming into contact with the material under treatment. The piston and piston-rod are formed out of one solid piece of steel, and the stamp-head is also of steel, with the exception of that portion that actually strikes the material, which is of chilled iron. It is very firmly secured to the piston-rod, and can be disconnected and replaced in a few minutes at a trifling cost. At *f* is a small horizontal oscillating cylinder, which is set in motion by opening the cock *g*, and supplying steam or air, as the case may be, through the supply-pipe. The piston-rod being attached, as shown, to a small disc-crank, causes the worm-wheel *h* to revolve, giving motion to the shaft *i* and friction-roller *k*, which latter, having a considerable bearing surface, causes by friction, the rotation on its bearing *l* of the large rotating bed or anvil *m*, which is shown in section. It will be noticed that the part of the bed immediately under the stamp-head is made of great strength and solidity, the entire pan weighing about 15 cwt. At *n* is a hand-wheel, which enables the attendant to raise or lower the cylinder whilst the machine is in motion, thus diminishing or increasing the distance between the bottom of the stamp-head and the inner surface of the rotating bed, as may be desired, from $\frac{1}{8}$ to $4\frac{1}{2}$ in. The stamp-head not being allowed to strike the anvil, it has simply to overcome the resistance due to the crushing. The material to be crushed, having been first reduced to pieces of a manageable size, is fed

FIG. 145.

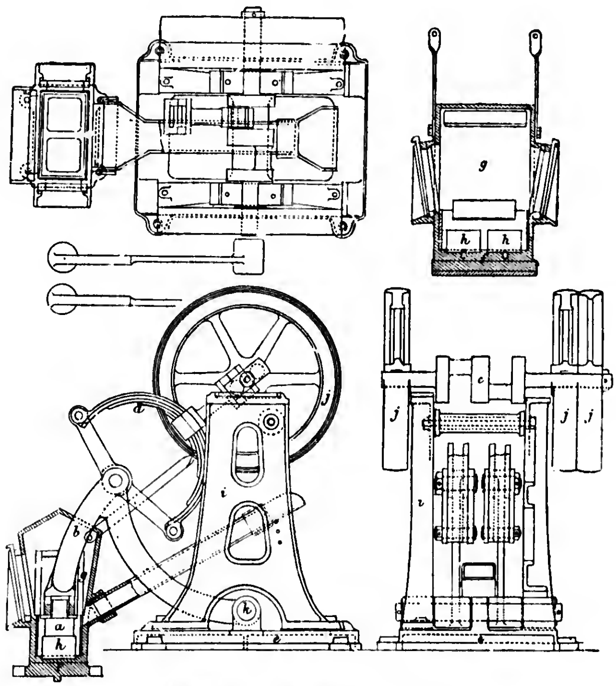


FISHER'S ROTATING-BED STAMP.

into the vessel *m* whilst the stamp is working, and can be reduced by the latter in a very short time to any degree of fineness required, the reduction being greatly assisted by the three combined motions, viz.: of the revolution of the bed *m* (which ensures a constant change and fresh supply of material at every stroke), the descending stamp, and the revolving and consequently grinding motion of the same at the period of contact, which motions, being concentrated at the same moment on a certain area of material, are said to have great effect in crushing, grinding, and pulverizing, either with or without water.

The material thus rapidly and effectually treated may be, in the case of quartz, discharged in the usual way, through the grating or wire gauze surrounding the bed, as shown at *o*, which, of course, can be of any form or mesh required; or, in the event of its being used as a flash battery, could be delivered through the pipe *p*, which can be made adjustable. It need scarcely be added that mercury for amalgamation, or other ordinary means for collecting gold contained in quartz, may be applied in the usual way.

FIG. 146.



PATTERSON'S "ELEPHANT" STAMP.

Patterson's.—In Fig. 146 is shown the "elephant" stamp invented by John Patterson, 9, Inverness Terrace, Kensington Gardens, which in appearance and character differs widely from other types of stamp heretofore used, and is stated to suit equally well for either wet or dry stamping. The most striking features in this stamp are the absence of all guide-rods and bushes, and extreme compactness and fewness of working parts, which reduce the friction and consequent wear. The two stamp-heads *a* are fixed in the ordinary way into two hammered scrap-iron levers *b*, which are attached to a 2-throw crank-shaft *c* by the intervention of two powerful semi-circular steel springs *d*. A great economy of power is effected by the peculiar action of the springs, storing up the force of the recoil from the blows of the stamp, which force is given out on the next return of the cranks. The power is further conserved by each stamp balancing its companion.

Some of the advantages said to be possessed by these stamps are that they are portable, can be taken to pieces and re-erected in a few hours, and need no special building. Foundations for the bed-plates *e*, as also for the anvil-block *f* under the coffer or mortar *g*, may consist of stone, concrete, or wood. The stamps can be fixed in any situation where there is a driving-shaft or wheel, and are independent of the position or nature of the motive power. All the parts are so strong as to resist any unusual strain. As the shoes or heads *a* wear, no alteration is needed, as the springs and flexible connections allow for varying distances between the face of the stamp-head *a* and anvil *h*, whether due to the wear of these parts or to the quantity of stuff on the anvil.

The quick napping nature of the blows ensures that there is no sliming of the stuff. Each head delivers 130 to 140 blows per minute. By varying the speed, the effect of the blows can be regulated at will to suit the degree of hardness or toughness of the stuff operated upon. The two heads will stamp 20 to 24 tons per diem of quartz, to the ordinary fineness. About 5 to 10 H.P. indicated will drive the stamps, according to the speed required. The continuous flow of the stamped stuff, owing to the quick action of these stamps, enables a much greater quantity to pass in a given time through the screens: the screen area, however, is about double what can be obtained in ordinary batteries per stamp-head. Where stamping and amalgamation are carried on simultaneously, the copper plates inside and outside the mortar require to present an area for deposit proportional to the work being got through by these stamps, so that the continuously discharged stuff may have ample time to be distributed over the plates.

The makers enumerate the following points as needing attention in erecting and working these stamps. The foundation, as in all other stamps, must be solid and unyielding. The die must possess sufficient inertia to withstand the powerful blows of the stamps, and so secure the maximum effect of the blows on the material operated upon, and not let any of it be wasted on the surrounding ground.

After the foundations are prepared, the top is levelled, and the holding-down bolts are in their places, the base-plate *e* is put into position, levelled accurately, and fixed with the holding-down bolts; the side-frames *i* are erected with their stay-pipe and through-bolt, and securely bolted to the base-plate already fixed; pedestals are put on top of side frames, and the double-crank shaft *c* is dropped in and the pulleys *j* strung on, seeing that they are clean and well oiled; the mortar-box *g* is let loosely into its place; the stamp-levers *b* are put in position, and the fulcrum-pin *k* and loose collar passed in; the connecting-rods and springs *d* are fixed; in coupling up to the levers *b* with the steel links and pins, the cramp is used for compressing the springs. The mortar-box is fixed permanently by means of the bolts into the vertical wood foundations; the dies are dropped into their places, and all round them are dropped a few pieces of broken stones, some gravel or sand, to keep them from shifting; the shoes are fixed into the lever-heads with strips or rings of copper round each shoe-shank; the crank-shaft is then turned round, and the levers, with shoes attached, are let gently fall on the die-faces several times, to secure the shoes home in their places. When placing the mortar-box and die in position, the face of the die should be 2 to 2½ in. lower than the face of the shoe, when the crank is turned to its lowest centre, the links being straight, and the shoe home in its place in the lever-head. Attention should be regularly given to keep the faces of the shoes and dies to this distance apart, as they become worn, by inserting packing slips of wood or iron between the undersides of the crank-brasses, and the upper ends of the connecting-rods, the tightening-bolts being made sufficiently long to effect this readily. The feed-shoot is fixed at such an angle as will cause the mineral to self feed. Special care must be taken that there be always some material on the die-faces for the shoes to hit, for if the dies get bare of material, the shoes may get broken by striking the dies. The washers on the bottom shaft must be a good fit between the levers, to prevent staggering. The shoes are turned when necessary to equalize the wear.

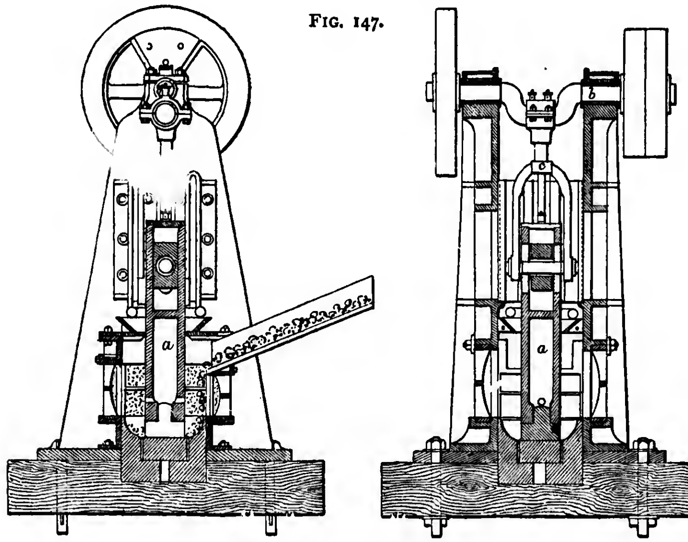
The following comparative statement of the cost of ordinary gravitation stamps, and elephant stamps capable of stamping 120 tons of hard gold-quartz per day of 24 hours, fine enough to pass wet through screens containing 900 holes per sq. in., is given by the inventor.

	Tons.	80 Heads Gravitation Stamps.	20 Heads Elephant Stamps.
		£	£
Cost delivered on rails at makers' works	..	4000	2500 0 0
Freight to and carriage in India Gravitation	160	1140	..
,, ,, Elephant	26	..	185 5 0
Approximate cost of cutting ground and building foundations ..	..	500	200 0 0
,, erecting	..	350	70 0 0
Time occupied, four months for Gravitation stamps	..	..	..
,, twenty days for Elephant stamps	..	..	..
Approximate cost of building houses, platforms for ore, &c.	..	1200	500 0 0
		7190	3455 5 0
Cost of power to drive (whether steam or water) for 300 working days of twenty-four hours each—			
Eighty heads Gravitation stamps, requiring 90 nominal horse-power at ½*d.* per hour per H.P.	..	1350	..
Twenty heads Elephant stamps, requiring 50 nominal horse-power at ½*d.* per hour per H.P.	..	..	750 0 0

The "elephant" stamp of slightly different pattern tried on the Pacific coast of America did not give altogether satisfactory results; but the manufacturers now claim to have overcome the difficulties.

Sholl's.—Sholl's pneumatic stamp is shown in Fig. 147: *a*, pneumatic cylinder and ram; *b*, crank-shaft; *c*, forked connecting-rod. The principal feature is the absence of glands, stuffing-boxes, and frictional surfaces, into which the pulverized ore can be flashed. The weight of the blow is varied by the speed. Great economy of power is obtained by storing compressed air in the cylinders, which is again utilized by expansion on the return of the crank, causing an elastic spring of air,

FIG. 147.



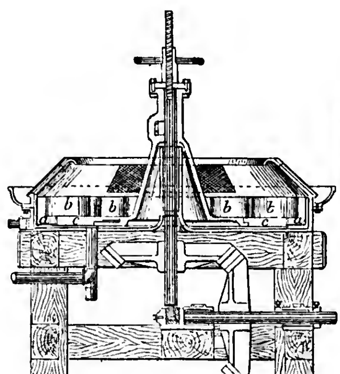
SHOLL'S PNEUMATIC STAMP.

released at every stroke. Ore which will pass through a 6-in. ring can be fed in. The shoe will bear the loss of 2 cwt. of its face before needing adjustment. A single head, to crush 12 to 15 tons per 24 hours, costs about 210*l.*; a double head, to crush 20 to 22 tons, 250*l.* The heaviest piece need not exceed 3 cwt.

Pulverizers.—A class of machines, designed to avoid some of the drawbacks to stamping batteries, has lately been introduced under the general term of pulverizers. Some work on the principle of grinding or triturating the material to a finely pulverulent condition, without the aid of blows, while others rely upon repeated concussion. Their chief forms are as follows.

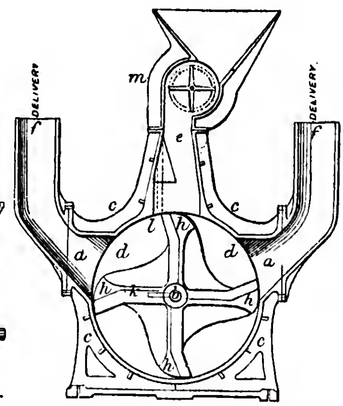
Howland's.— The Howland pulverizer, as made by Morey & Sperry, Liberty St., New York, is shown in Fig. 148. *a b c* are the wearing parts, which are made of the hardest iron, in duplicate, and can be changed with less trouble than the shoes of the stamp-mill, no keys or bolts being required to hold them. *a* is an L-shaped ring of the full diameter of the inside of the machine. *b* are rings or rolls 10 in. in diameter, 4½ in. face; 12 of these are used upon the disc-plate *c*, which must run at 175 to 180 revolutions per minute; the rings *b* rest partly upon the outer ring *a*, which is stationary. The motion of the disc-plate *c* imparts a peculiar motion to the rings or rolls *b*, they turning as it were upon a central axis, spinning like tops, while the whole 12 at the same time run around the large circle, being thrown off by centrifugal force. The pulverizing is done between the rolls or rings *b* and the outer ring *a*. The aggregate weight of all the wearing parts is about 2135 lb. The machine will pulverize, it is said, 500 to 750 tons of ore to 40-mesh and finer, with one set of the wearing parts, which is less wear

FIG. 148.



HOWLAND PULVERIZER.

FIG. 149.



JORDAN'S PULVERIZER.

or loss of iron than in stamping the same amount of ore to same grade of fineness. The ore is fed through the opening in the top of the bonnet-casting; immediately on falling upon the revolving disc-plate, it is carried outward by centrifugal force to the rings or rolls, and when pulverized fine enough, is ejected through the screens to a circular trough conveying it to copper plates for amalgamation, or run into tanks for settling. The machine can also be constructed for dry pulverizing, when it will accomplish about one-fourth less work. The frame for the machine is made of Southern pine timber, mortised and tenoned throughout, and held by strong joint-bolts. An automatic feeder is provided especially for this machine, that will feed the ore continuously, as well as a rock-breaker, adapted to breaking the ore to the proper size for the machine, which must be no larger than 1 in. This machine is said to pulverize wet, hard quartz rock to a fineness that will pass through a 40-mesh screen, at the rate of a ton per hour, and will pulverize dry, to pass through a 60-mesh screen, $\frac{1}{2}$ to $\frac{3}{4}$ ton per hour. Every exposed part of what might be termed the wearing castings, namely, the pan-ring, the revolving disc-plate, and the rolls, are continually passing and repassing each other at different points with a rolling and grinding action, ensuring a maximum of wear from a minimum of metal. These wearing castings are not held in the machine by a single bolt, but simply by gravity alone, hence are easy of removal when worn too thin for further use. It can be set up and run in a few hours after arriving on the ground, and requires no expensive foundation. To run the machine, 12 to 15 H.P. is required. The weight of the machine, including frame complete, is less than 7000 lb., and the weight of the heaviest piece is 855 lb. The weights of the wearing parts are :—1 outer ring, 765 lb. ; 1 disc-plate 655 lb.; 12 rolls or rings, 714 lb.; total, 2134 lb.

Jordan's.—The pulverizer made by T. B. Jordan & Son, 52 Gracechurch St., E.C., is shown in Fig. 149. Two circular dished castings *a*, each having a long bearing *b* projecting from its centre, are bolted together by their flanges *c*, and form the crushing-chamber *d*, which has an inlet-opening on the top *e*, and two outlet-openings *f*, one on each side. The two bearings carry short wrought-iron spindles at *b*, which meet end to end in the centre of the crushing-chamber. On the inner end of each spindle is keyed a set of 4 arms *h*, the diameter of the chamber, the surfaces of the one set of arms being so angled at 45° with the horizontal centre line that they are parallel to and face those of the other set. These arms pass in opposite directions close to each other, and to the sides of the chamber, and their backs are so formed as to create a blowing or fan action in the chamber, drawing air through openings in the sides and near the centre of the chamber. On the outer end of the spindles, at *b*, are keyed pulleys for driving by belts, the spindles and their arms and pulleys being quite free and independent of each other to turn in reverse direction. One of the said spindles, at *k*, has a worm engaging a wheel, and working the vertical shaft *l*; this again drives at a given speed the automatic feeder *m*. By means of the pulleys and driving-belts, the spindles and arms are revolved in reverse directions at any suitable speed for the material to be crushed. The material falling into the chamber from the automatic feeder *m* is struck by one of the arms (owing to the angle of its face) into the path of those revolving in the reverse direction, and is by them, for the same reason, immediately returned, this operation being repeated as long as necessary. The fineness of the material leaving the machine is regulated by the current of air, which at once takes away all particles light enough for its force to suspend, and the force of this current can be adjusted to the greatest nicety by simply closing or opening the apertures in the casing provided for the purpose. The machine is thus adapted only to dry crushing.

Lucop's.—It is claimed for Lucop's pulverizer, made by Beverley & Atkins, Wicker, Sheffield, that it will reduce 25 cwt. of quartz per hour with a 4-H.P. portable engine working at 40 lb. pressure on the boiler and 150 rev. of crank-shaft, while the first cost of the D size machine is but 150*l.*, and the repairs come to less than 3*d.* per ton dealt with.

Thompson's.—The action of Thompson's pulverizer consists in the use of a heavy ball within a revolving drum, the ball being thrown by centrifugal force against the material to be crushed. The size weighing 5 tons, and running with a 190-lb. ball, requires 10 H.P., and pulverizes 60 tons per 24 hours to a degree that allows it to pass through a No. 60 screen.

Arresting the Metal.

General Principles.—The operations hitherto described have had for their object the disintegration of the material containing the gold, in order that the latter might be liberated from the worthless material accompanying it in nature. The next step is to arrest and recover the valuable portion thus set free. This valuable portion is not all of one quality, but consists of two classes of material, one being gold in a clean, uncontaminated, "free" state, the other composed of various metallic sulphides (of iron, copper, lead, zinc, antimony, &c.), commonly known generically as "pyrites," having more or less gold concealed within and between its crystals or grains. The separation or elimination of the valuable ingredients of the mass, the free gold and the pyrites, is effected by a combination of two distinct processes. The first consists in directing the pulverized or comminuted mass of ore through, over, or among a body of mercury, which metal possesses the peculiar property of absorbing all particles of free gold with which it comes into sufficiently close contact. This absorption is known as "amalgamation," and as it constitutes the most certain and satisfactory method of collecting the minute particles of gold, from which the mercury can afterwards be separated without loss, and used an indefinite number of times, the object of all preliminary operations is to prepare the gold for amalgamation. The second half of the twin process of arresting the metal is the provision of a number of checks or obstructions to the onward flow of the matters leaving the reduction apparatus, with the object of presenting abundant opportunities for the valuable matters to avail themselves of their comparatively greater specific gravity to come to rest, while the worthless matters and a portion of the pyrites flow away in the current of water, to undergo further treatment afterwards.

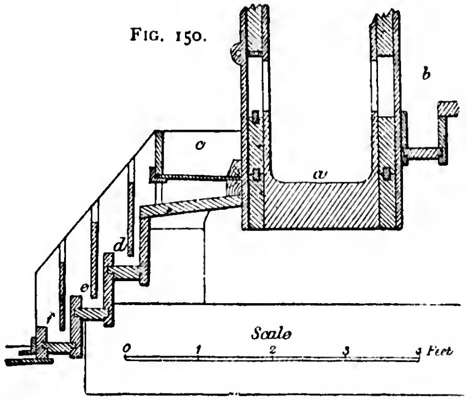
The subject may be divided into the following heads:—(1) mercury applied in its ordinary fluid condition, (2) mercury applied as a coating on metallic surfaces, known as amalgamated plates, (3) special forms of amalgamator, for rubbing up the material with the mercury, and (4) blanket-tables.

Mercury.—Perhaps the commonest way of using mercury, and certainly by far the most general in the United States, is to supply it in regular or irregular quantities directly into the mortar or coffer of the stamps, so that it may be pounded up with the mineral. When this plan is adopted, amalgamated plates, to be described presently, are almost invariably employed in the mortar. The use of mercury in this manner would appear to be radically wrong. In the first place, the smashing and splashing of the mercury under the stamps must cause a considerable loss, for the simple reason that tiny particles of metal will be carried away by the force of the current, without ever having an opportunity to come into contact with the plates, or to deposit themselves subsequently. In addition to this, it may be broadly said that every gold-ore contains some pyrites. The stamping operation reduces this to a very fine state, and even liberates some of the sulphur to such a degree that it will form a coating over the globules of mercury and amalgam, which is technically known as "flouring" or "sickening," and by which the power of amalgamation with gold is destroyed, or reduced to a minimum. When amalgamation is alone depended upon for catching the gold, this circumstance will entail a triple loss,—a loss of gold which has escaped amalgamation, and a loss of both the gold and mercury which have become amalgamated, for the floured stuff, whether mercury alone, or mercury which has absorbed some gold, cannot be caught by contact with a fresh mercurial surface.

The second mode of exposing mercury to the crushed material may be divided into two heads, "ripples" or "riffles," and "troughs." Mercury-ripples consist of grooves cut across the ripple-board tables, inclined planes of wood, varying in length, placed in the route of the materials leaving the stamps. These grooves are cut about 2½ ft. apart, and are 1 in. deep at the lower side, diminishing till they are flush with the surface of the bath at the upper edge, and about 3 in. wide. While at work, they are kept nearly full of mercury. They are generally used in combination with blanket-tables, and are most favoured in Australia.

The mercury-trough may also be considered as essentially Australian. A very effective arrangement of mercury-troughs and blanket-tables, adopted by some of the largest Victorian companies, is as follows:—The material leaving the stamps is led into a trough, having a perforated plate at the bottom to keep back any coarse stuff, by which it is easily distributed; thence it passes into 3 connected troughs, containing mercury, dropping from the first into the second, and from the second into the third. Each of these troughs is fitted with a splash-board, which, reaching down to within a certain distance of the bottom, compels the falling matter to penetrate the mercury more or less, before escaping over the lip of the trough. Each trough has a tap-hole on one side, by means of which the amalgam may be drawn off. The whole of the contrivance is under lock and key, which prevents stealing. At the end of the blanket-table, another similar trough is placed, through which the material passes before entering the waste-trough. The amalgam formed in all these troughs is periodically removed. Fig. 150 shows the exact arrangement adopted by the Port Phillip Co., at Clunes:—*a*, stamper-box or mortar; *b*, back escape; *c*, perforated plate; *d*, *e*, *f*, mercury-troughs.

FIG. 150.



PORT PHILLIP MERCURY-TROUGHS.

Amalgamated Plates.—Amalgamated plates are prepared by a somewhat delicate and tedious process of covering one side of pieces of sheet copper with a coating of mercury. That portion of the interior of the batteries which is not occupied by the screens is lined with these plates, fixed in an inclined position, and so as to be readily removed and replaced. By the churning that takes place in the battery, particles of gold, mercury, and amalgam are splashed upon these plates, and attach themselves to the surfaces, which are periodically cleaned. Outside the batteries are placed tables, covered with similar amalgamated plates, adjusted at such an inclination as will permit a ready flow of the materials over the surface, without being so rapid as to wash away the gold and amalgam, or prevent their adhesion to the plate. The inclination necessarily differs according to the supply of water, and other conditions. The gold and amalgam collected on these plates are removed in the same way as from the others.

There are two ways of fixing these copper plates in such a position as will bring them into constant contact with the crushed ore and the thereby liberated particles of gold. Firstly, the mortars are cast purposely to receive, on proper shelves, this copper-plate lining; and, secondly, the old boxes may be at once adapted for the same purpose until a renewal is necessary, when the first-named should be obtained and no other. It may be mentioned in passing that such mortars prevent any possibility of peculation of amalgam.

The first-named kind of mortars (Fig. 151) are cast to a pattern, so as to introduce beneath the rim for the gratings (inside the mortars) a kind of sloping shelf 4 in. wide for the whole length of its front discharge, at an angle of 30° to 35° towards the false bottoms. Into this shelf, 4 holes *e* are drilled, or recesses cast ½ in. in diameter and 1½ in. deep, which are plugged with dry and soft wood. A copper plate of the exact size of this shelf, ¼ in. thick, is laid on a strip of blanketing equal in size, and 4 copper screws are inserted through corresponding holes ⅛ in. diameter, in the copper-plate and blanketing into the wooden plugs, which, on getting

Fig. 151.

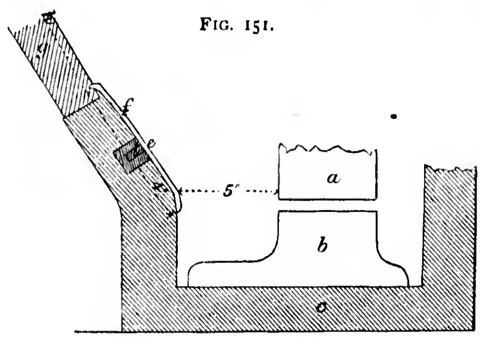
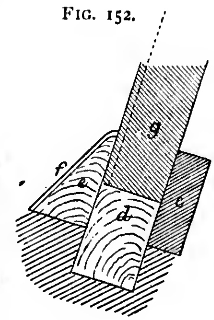


Fig. 152.



Fixing Amalgamated Plates.

wet, will swell, and thus the plates are securely screwed down until the next cleaning-off, when they are unscrewed, and so forth. Both the upper and lower edges of the plates should receive a batter, in order to make a good joint, and to prevent the finely-crushed ore getting behind. Any subsequent repairs should be made with copper rivets, and, in fact, the more battered these plates become, the better are they for the interception of gold. The explanations of the illustration are :—*a*, shoe ; *b*, die ; *c*, box ; *e*, holes plugged with soft wood ; *f*, copper plate ; *g*, grating-frame ; *h*, line for grating ; *i*, screw countersunk in copper plate.

The other method does not necessitate the immediate change in the pattern of the boxes in use until they are unfit for use, and the adaptation of old boxes for these copper plates does not interfere with their efficacy. The ordinary frame *g*, which holds the gratings, is not quite so high, in order that a piece of soft wood *d* (Fig. 152) may be screwed on to its lower part at *d* ; it is 3¼ in. high and 1¾ in. wide ; and at the same time the cast-iron lug *c* is made higher by broad strips of boiler-iron, so as to catch both the wooden insertion and the grating-frame properly. At the inner side of the piece of wooden insertion *d*, a triangular strip of soft wood *e* is screwed on, which has the prepared copper plate *f* fixed to it, and in this manner the plates will act nearly as well as in the other case. The plates used inside the mortar are $\frac{1}{8}$ to $\frac{1}{4}$ in. thick, while outside $\frac{1}{16}$ in. sheet copper suffices.

When ordinary copper plates are to be employed, they are prepared in the following way :—The copper must be of the very best quality, and should not have been rolled to such an extent as to make the surface bright and hard, as it will not then possess the necessary porosity for absorbing the mercury. In such a case, it must be annealed before use, which is generally done by heating the plates beneath till wood will ignite on the upper surface, taking care that the heating is uniform, and avoiding oxidation of the upper surface during the process. The plate is then flattened by beating it with a wooden mallet with a flat slab to bear the blows, as direct blows would batter the surface. The fixing of the plates in the mortar has already been described ; it may be noted, however, that the screws should be either of copper or extremely hard wood. When the plate is secured, its surface is dressed smooth with the mallet and slab, and then scoured with sand and wood-ashes, and rubbed perfectly bright with very fine emery-cloth ; or it may be washed with a strong soda solution, which removes grease and imparts a bright face. Next it is washed with clean water, and rubbed over with a solution of potassium cyanide, in the proportion of $\frac{1}{2}$ oz. in 1 pint of water, taking care to finally wash with warm water, as any excess of cyanide would dull the surface. The bright clean plate is then ready for the mercury, and is rubbed with a mixture of fine mill tailings or other fine sand and powdered sal ammoniac, applied with a brush, while a little mercury is sprinkled on the surface so long as the copper absorbs it. The addition of the sal ammoniac to the sand for rubbing in removes the effects of oxidation, which sets in very rapidly on the exposed surface, and prevents amalgamation. The mixture is left on the plate for $\frac{1}{2}$ hour, when the latter is rewashed with cyanide solution, and more mercury is added until absorption ceases. Gold-amalgam (or, failing it, silver-amalgam) is then rubbed in with a piece of indiarubber belting, using sal ammoniac solution to keep the surface bright.

When electro-silvered plates are used instead of simple copper ones, they are prepared in the following manner. They are well cleaned and burnished with very coarse sand-paper, after being straightened out ; a coat of good beeswax is then applied to the side not cleaned, in order to confine the process to one surface only. The plates thus prepared are hung in a bath containing a solution of silver of regulated strength, then connected with a battery, and thus electro-plated with pure or coin silver on one side, in such a manner and with such a quantity of silver as will not amount to less than 1 to 3 oz. per sq. ft.; any larger percentage is preferable, if the coating presents as rough a surface as possible. These electro-silvered copper plates are highly esteemed for their amalgamating powers, as the copper and silver form, as soon as the mercury is applied in the usual way (just described), a powerful galvanic battery, the action of which is much heightened by the slightly acid character imparted to the water by the crushing of pyritous matters. A well-known maker of these silvered plates is E. G. Denniston, 653, Mission Street, San Francisco.

The cost of the ingredients used for a 5-stamp battery in 10 months, at Californian prices, is thus given by Thureau:—

	$	c.
6 Bunsen's elements	24	00
4 glass cylinders	3	20
5 lb. cyanide	4	25
1 porous cup	0	50
7 lb. nitric acid	1	15
50 lb. cyanide (fused)	37	50
14 lb. nitric acid	2	50
(14*l.* 12*s.* 1¾*d.*)	73	10

The highly favourable opinions first expressed with regard to amalgamated plates have had to be modified by subsequent experience. [illegible] require constant attention, and to be kept free from film, which is very liable to form on the surface, and will altogether prevent amalgamation if not removed. For this purpose, sal ammoniac, potassium cyanide, and ammonium chloride are used to wash the plates, they destroying greasy adhesions and dissolving the oxides of copper and other metallic salts caused by the action of the water employed in the battery, which almost always contains mineral salts in solution. All things considered, under ordinary circumstances, amalgamated plates probably never catch more than 55 per cent. of the gold-assay of the ore, and when other appliances are not adopted in conjunction with them, the loss of gold may amount to half the original quantity present. It may be safely said that their use has been abandoned on all properties where any pretence is made of saving above 80 per cent. of the ascertained gold-contents of the ore.

Raymond expresses himself in the following terms concerning the results of using amalgamated plates. The product of gold varies between 30 and 50 per cent. of that in the ore, and averages 40: 15 per cent. of the total gold remains in the unredeemed portion of the ore, and thus 45 per cent. actually freed still escapes the plates,—7 per cent. being dissolved in the ⅔ of the mercury charged, which also escapes, and 38 per cent. escaping as unamalgamated gold. Of the amalgam obtained, the interior plates yield about 67 per cent., the outer 20 per cent., the skimmings 13 per cent.; or the inner plates yield $\frac{3}{4}$ and the outer plates $\frac{1}{4}$ of the amalgam obtained, or 30 and 10 per cent. respectively of the gold contained in the ore. Reckoning by units of surface, the inner plates collect 36 times as much gold as the outer.

Bland found amalgamated plates less efficient than mercury-drops and blanket-tables for the Port Phillip treatment, but thinks they may be useful where mercury is put into the mortars.

Amalgamating Pans.—The term "pan" is used generically to denote a very large class of machines working on the same principle as the snuff-muller. Some are intended only to rub the ore against a surface of mercury, while others at the same time more thoroughly grind it. To the former class belongs the Hungarian bowl or Tyrolese mill (p. 1041), while the latter includes the *arrastra*, the Italian *molinari*, the Chilian mill (described on p. 1038), &c.

Pans present a great variety in the details of their construction. The common features are a round tub, usually of cast iron, but sometimes with wooden sides, 4 to 6 ft. in diameter and about 2 ft. deep, having a hollow pillar cast in the centre, within which is an upright shaft projecting above the top of the pillar that may be set in revolution by gearing below the pan. To the top of this shaft is attached, by means of a key or feather, a yoke or driver by which the muller or upper grinding surface is set in motion. To the bottom of the pan, on the inside, is fixed a false bottom of iron, cast either in sections, commonly called dies, or in one piece, having a diameter a little less than that of the pan, and with a hole in the centre adapted to the central pillar. This serves as the lower grinding surface. The muller, forming the upper grinding surface, is usually a circular plate of iron corresponding in size and form to the false bottom just described, having a diameter nearly equal to that of the pan, and a flat, conical, or conoidal form, according to the shape of the pan-bottom. Its under side is furnished with shoes or facings of iron, about 1 in. thick, that may be removed when worn down, and replaced by new. The muller is attached to the driver, which is put on and over the central pillar of the pan, and, being connected with the interior upright shaft as described, is thus caused to revolve. There are various appliances for raising or lowering the muller, so that it may rest with its whole weight upon the pan-bottom, in order to produce the greatest grinding effect, or be maintained at any desired distance above it, when less friction or more agitation is required. Various devices are also in use for giving proper motion to the pulp, so that, when the muller is in revolution, the material may be kept constantly in circulation, passing between the grinding surfaces and coming into contact with the mercury. Some pans are cast with a hollow chamber, 1 to 2 in. deep in the bottom, for the admission of steam, in order to heat the pulp, while others employ only "live steam," which is delivered directly into the pulp by a pipe for that purpose.

The quantity of ore with which a pan is charged for a single operation, varies from 600 or 800 to 4000 or 5000 lb., according to the size of the pan. The ordinary charge of pans most generally in use at present is 1200 to 1500 lb.

In charging the pan, the muller is raised a little from the bottom, so as to revolve freely at first; water is supplied by a nose-pipe, and at the same time the sand is thrown into the pan with a shovel. Steam is admitted either to the steam-chamber in the bottom of the pan or directly into the pulp. In the former case, the temperature can hardly be raised as high as in the latter; but, on the other hand, when steam is introduced directly, care is necessary to avoid reducing too much the consistency of the pulp by the water of condensation. The pulp should be sufficiently liquid to be kept in free circulation, but thick enough to carry in suspension, throughout its entire mass, the finely divided globules of mercury. In some mills, both the methods of heating are employed in the same pans, the temperature being first raised with each charge by live steam, and afterwards sustained by admitting steam to the chamber only. Some pans are covered with wooden covers to assist in retaining the heat. When properly managed, the temperature may be kept at or near 200° F. (93° C.). When, in the use of live steam, the pulp becomes too thin, the supply of steam is cut off, the covers are removed, and the pulp is allowed to thicken by the evaporation of the water. The steam in the chamber may keep the temperature up to the desired point in the meantime. Another advantage of the steam-chamber is that exhaust-steam from the engine may be used in it, while for use in the pulp it is better and customary to take steam directly from the boilers, because that which comes from the cylinder of the engine is charged with oil and is injurious to amalgamation.

The muller is gradually lowered after the commencement of the grinding operation, and is allowed to make about 60 or 70 revolutions per minute. In the course of an hour or two, the sand should be reduced to a fine pulpy condition. When this has been accomplished, and by some mill-men at a still earlier stage, even at the beginning of the operation, a supply of mercury is introduced into the pan, the muller is slightly raised from the bottom to avoid too great friction, which would act to the disadvantage of the mercury, and the action is continued for 2 hours longer, during which the amalgamation is in progress. The mercury is supplied by pressing it through canvas, so as to scatter it upon the pulp in a finely-divided condition. The quantity varies greatly in different mills, the ordinary supply being about 60 or 70 lb. to a charge of ore consisting of 1200 or 1500 lb. In some mills, a quantity, varying from 75 to 200 or even 300 lb., is put into a pan when starting after a clean-up, and subsequently a regular addition of 50 or 60 lb. is made with each charge.

Two hours having been devoted to the grinding, and two or three more to amalgamation, the pan is discharged, and its contents are received by a settler or separator. The discharge of the pan is usually aided by a supply of water, which dilutes the pulp and permits it to run freely from the pan into the settler. The pan, being emptied and partly washed out by the stream of water, is again charged with a fresh quantity of sand, and the grinding operation is resumed without delay.

The main objects sought for by inventors of pans have been to produce grinding surfaces of most effective form, securing the greatest uniformity of wear with economy of power; to obtain the most favourable conditions for amalgamation, depending mainly on the free circulation of the pulp, the uniform and thorough distribution of the mercury, and the proper degree of heat; and to combine, with these requirements, simplicity and cheapness in construction, facility in management and repair, large capacity, and economy of time, labour, and materials in the performance of duty.

The attempts that have been made to obtain these results have met with varied success, the different devices of any one pan sometimes obtaining a high degree of excellence in certain details at the cost of it in others.

Among the differences in characteristic features of pans, the most noticeable is that of the bottom and the grinding surfaces, some being flat, and others variously curved; other details, of more or less importance, such as the construction of the muller and the method of attaching it to the driver, the form of the shoes and dies, the means of fixing them in place, of providing for the heating of the pulp, and for its circulation during the grinding and amalgamating process, vary considerably in the several patterns.

The opinions of practical mill-men are somewhat divided regarding the comparative advantages of the different forms of pan-bottoms. The prevailing opinion, however, seems to be, all things considered, in favour of the flat bottom. While other forms of grinding surface may possess superior advantages theoretically, their greater efficiency in practice is often lost by the unequal wear of the surface of the muller, usually resulting from the difficulty of keeping the other parts of the machine, on which the grinding surfaces depend, in perfect order. The various parts of the flat muller are simpler in form, more easily handled, and more conveniently replaced when worn out. The flat-bottomed muller involves the expenditure of more power in carrying its load of thick pulp; but this disadvantage is counterbalanced, in the opinion of some, by the more complete distribution of the mercury, and the consequently more perfect amalgamation.

The various forms may now be considered in alphabetic order.

Berdan's pan.—Berdan's was one of the earliest and crudest kinds of pan, and is now almost obsolete. Its operation is very slow, only treating about 10 cwt. per 24 hours. It is occasionally employed on tailings.

Britten's pan.—This is one of the simplest forms of pan, consisting only of a concave basin containing a muller, which is rotated by means of a manual fly-wheel and a pair of bevel-wheels.

Chilian mill.—The Chilian mill is nothing more nor less than an edge-runner mortar-mill.

Denny & Roberts' pan.—The pan made by Denny & Roberts, Ballarat, Victoria, is highly esteemed in Australia, extracting 90 to 95 per cent. of the gold from ordinary tailings, and 70 per cent. from concentrated pyrites. The top pan is keyed on to the main inclined spindle, which makes 25 revolutions per minute when treating ordinary poor tailings, and 20 to 22 revolutions for rich blanketings. The middle pan runs about $\frac{2}{3}$ of the speed of the top pan, and is driven by a belt from the horizontal shaft, which gives motion to a small horizontal spindle running in bearings bolted to the bottom frame of the machine. This spindle has a pinion keyed on to its inner end, which engages with a crown wheel that gives motion to the pan. The middle pan has no connection with the main inclined spindle; it is supported by a cast-iron bracket, on which it revolves the opposite way to the top pan.

The lower pan makes a little more than $\frac{1}{3}$rd of the revolutions of the top pan; it is also driven by a belt from the horizontal shaft, giving motion to a horizontal spindle running in bearings bolted to the bottom frame of the machine, having a pinion keyed on to its inner end, which engages with a crown-wheel for giving the pan motion in the same manner as the gear for the middle pan, only on the opposite side of the machine.

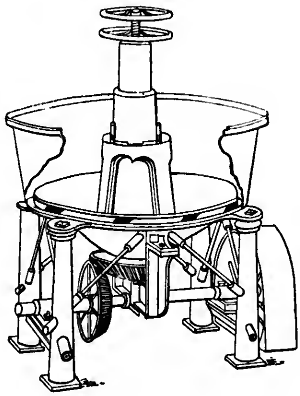
The top pan has a rotary grinder, the section of which is made to correspond with the section of the inclined pan, both having true conical lines, thus ensuring perfect grinding between the two surfaces without causing much wear and tear of parts in contact. This rotary grinder weighs about 7 cwt.; its spindle runs in loose boxes; these latter are kept in place by steel springs, which are made to act as levers for weighting the roller, by means of wheel-nuts. The operator may increase the crushing power of the rotary grinder 50 per cent. by taking a few turns on the wheel-nuts; this is only necessary when crushing the rough stuff left in the stamper-boxes on washing up, or any like material.

In addition to the rotary grinder, there are two disintegrators fitted opposite the main inclined shaft on the down side (the reader will understand that the down side means that portion of the pan which when revolving has passed the rotary grinder and is going to the lower side); these disintegrators weigh about 1 cwt. each, and are fitted with a white-metal shoe, which has a section corresponding with that of the pan. This shoe when fitted into the disintegrator presents a surface to the pan it stands in of only $\frac{1}{4}$ in.; when the shoe is in its place, the down side of it is perpendicular to the surface of the pan it works in, and the upper surface forms an angle of about 45° with the surface of the pan, thus leaving a wedge opening of 45° for the material under treatment to pass. In order to ensure the passing of the material under the disintegrators, and to prevent its floating round the sides where it would escape the disintegrating action, the shoes are made with a fluted or corrugated surface, which admits the material under operation, thus preventing any escape. The material to be operated on is admitted to the top pan, between the rotary grinder and the disintegrator; then whatever gold is liberated by the frictional action of the disintegrator is carried by the revolutions of the pan directly to the mass of mercury in the lower angle of the pan, which presents a broad surface to take it up and amalgamate it, while the coarse matter is carried on and raised by the revolution of the pan mixed with particles of mercury, and is passed beneath the rotary grinder, which reduces it to fine powder preliminary to a successive action of the disintegrator and a successive action of the mass of mercury. As there is a continual supply of water to the upper pan, it overflows at its lower side, and the overflow, which consists of water and particles of matter fine enough or light enough to be carried with it, passes to the mercury amalgamating-well, which receives the liberated gold and silver. The particles of metal by their specific gravity assist greatly in amalgamating with the mercury in the well, as in falling from the edge of the pan they, having a perpendicular fall of 10 in., plunge into the mercury, where they are secured. From the mercury-well in the top pan, the pulverized matter and water pass on to a cast-iron apron, which directs them to the inside of the second pan, where they meet the upward current caused by the pan revolving, and are then carried into the annular channel, which contains mercury, when they pass round by the revolutions of the pan, and meet with the same action from this disintegrator and mercury as in the top pan. This second pan is fitted with 3 disintegrators, the same shape as those in the top pan, but lighter. The particles of fine metal, still associated with sand, pyrites, &c., that flow out of this pan, fall on to a cast-iron apron, which directs them into the upward current of the lower pan, when they are subjected to the same treatment as in the second pan. The top pan from its fast speed only liberates the coarse metal; the second pan, which revolves on a cast-iron bracket and has no connection with the main inclined spindle that carries the top pan, liberates the next heaviest of the remaining metal; and the lower pan, being large and having 4 disintegrators, besides a mercury-well, by its slow speed causes scarcely any agitation in the water, so that the very finest particles of metal are liberated and amalgamated. The disintegrators in the lower pan are of the same shape and weight as those in the middle pan, and the pan is supported by the same brackets as the middle pan, only it revolves on a different surface or part of the bracket; like the middle pan, it has no connection with the main inclined spindle; it may thus be made to run any number of revolutions by changing the pulleys.

Dickson's amalgamator.—This apparatus has a supply-hopper and a series of downward and upward passages connecting with scroll-shaped chambers, arranged so that the pulp from the stamp-mill is spread out in thin sheets, and the current is made to revolve with great velocity, so as to bring the gold and mercury in the chambers into intimate contact. The amalgam remains in the chambers, but the lighter particles escape from one chamber to another, and are finally allowed to pass away through the discharge-sluice. The velocity of the water is regulated by plugs in the side of the discharge-sluice.

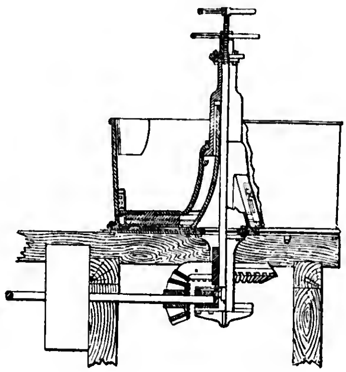
Hepburn & Peterson's pan.—The bottom of this pan, Fig. 153, has the form of an inverted cone, inclining toward the centre. The bottom is covered with 4 dies of corresponding form, which are secured in a similar manner to Wheeler's. Steam is introduced directly, without a steam-chamber in the bottom. In the centre of the pan rises a hollow pillar, through which passes the driving-shaft. The shape of the muller corresponds with that of the bottom; at the centre it has an upright hollow cone, by which means it is connected with the hub or driver. The under side of the muller is furnished with shoes, between which, when attached to the muller, is a channel or radial passage left for the circulation of the pulp. The muller also contains radial grooves between the shoes, so that, when the latter wear down, the channel may still be large enough to permit an easy movement of the material. The muller is raised or lowered by means of a screw and movable nut at the top of the hub, the screw resting on the top of the driving-shaft to which the hub is keyed. The circulation of the pulp in this pan is effected without the use of wings or guides, such as are commonly employed in other pans for this purpose. When the muller is in motion, the pulp, passing between the grinding surfaces from the centre to the circumference of the pan, descends again by its own weight towards the centre, on the upper side of the muller: a movement promoted by the conical shape of the muller-plate. In the use of guide-plates or wings to aid the circulation, a difficulty is sometimes experienced in the tendency of coarser sand to settle and pack firmly, if the pan is stopped for a little while, giving much trouble in starting again. By thus dispensing with the use of wings, some inconvenience is avoided. The charge of the pan is about 1500 lb., usually working 4 hours on a charge. It runs at 60 to 70 revolutions a minute.

FIG. 153.



HEPBURN & PETERSON'S PAN.

FIG. 154.



HORN'S PAN.

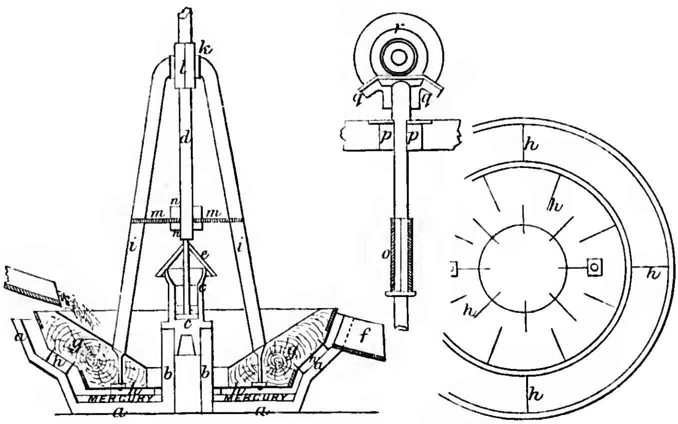
Horn's pan.—Horn's pan, Fig. 154, is cast in one piece, and has a slightly flaring or irregularly concave surface. Around the dies is a depressed annular space 3 in. wide, traversed, as the muller rotates, by an arm which reaches to the bottom. The muller is raised by a screw at the top. The bottom is double, to afford an annular space for steam to heat the charge.

Hungarian bowl.—The Hungarian bowl or Tyrolese mill, Fig. 155, consists of 3 main parts—the basin or bowl, the runner which revolves inside it, and the arrangement for transmission of power to the mill.

The basin *a* is of cast iron, ½ in. thick, 6½ in. high, 24 in. diameter at top and 18 in. at the flat bottom inside. An iron cylinder or pipe *b*, which rises for 4 or 5 in., is cast to the centre of the basin. This pipe has 3-in. outer, and 1½-in. inner diameter, and serves for the reception of the lower pivot bearings *c* of the spindle *d*. These bearings *c* consist generally of iron, and are protected against the influx of sand, &c., by a mantle or hood of sheet iron *e*. About 3½ in. above the bottom is a hole, 4 in. broad, in the rim of the basin, to which a tin or sheet-iron outlet *f* is riveted. The fixing of the basin to the planks of the floor is effected in a simple manner, either by screws through two ears, cast opposite to each other on to its bottom, or the latter is cast with a projecting rim, over which iron claws or hooks are driven into the floor.

The runner *g* is constructed of pine-wood, of the exact shape of the inside of the basin, but of somewhat smaller size, and is furnished at top with a wide funnel-shaped cavity, which communicates with a cylindrical hole of 5 in. diameter through the centre. Its size and shape are such that, when suspended centrally in its proper position in the basin—the hole just mentioned allowing it to go freely over the cylinder above described,—its surface is parallel to the inner surface of the basin, and leaves an open space, $\frac{3}{4}$ in. broad round the side, and $1\frac{1}{2}$ in. at the bottom, and it projects about 1 in. above the top of the basin. Two thin

Fig. 155.



Hungarian Bowl or Tyrolese Mill.

sheet-iron hoops round the circumference protect it against cracking, and its bottom is armed with about 20 blades or knife-like scrapers *h*, of sheet iron, $\frac{1}{2}$ in. thick and $2\frac{1}{2}$ in. long, which are radially driven into the wood, each projecting exactly $\frac{3}{4}$ in. The central connection of the runner with the spindle is in some cases effected after the old method, by means of a tripod; but this will be gradually superseded by the generally applied and more practical new arrangement of a wrought-iron fork *i* with two prongs, which are driven through the runner and screwed tight, whilst a square collar *k*, formed at their junction, is slid over a square portion *l* of the spindle; 6 or 7 in. below this part, the prongs are connected by an iron cross-bar *m*, which fits with a flat, round collar over the spindle, where the latter has, for several inches, screw turnings. Two nuts *n*, one above, the other below the collar, serve both for fixing the runner and to adjust it—i. e. to raise or lower it according to requirement. Each spindle has, a few inches above the upper collar, a coupling *o* for the purpose of throwing the runner out of action, without interfering with those of the other mills.

For the transmission of motive power from the axle of the water-wheel to the set of mills attached to a stamping-machine, three different methods are in use, viz. by endless straps and pulleys, by cranks, and by mitre-wheels. The last arrangement is the one most approved, and will therefore gradually replace the others; for it ensures not only a better and more undisturbed working of the mills, but, though more expensive in the first instance, is ultimately cheaper as regards wear and tear. The construction is as follows: The pivot at the upper extremity of each spindle turning in a collar of white beechwood *p*, inserted in the horizontal beam of the framing, carries, at its end that projects a few inches above the beam, a small horizontal mitre-wheel *q*, 6 in. in diameter, with 21 teeth; this wheel is turned smooth on its lower side, which rests upon an equally smooth iron plate, let into and secured by screws to the beam. Sometimes the end of the spindle is enlarged, and the rim rests upon the iron plate. All the mitre-wheels of the mills standing in one row are connected with corresponding vertical ones *r* of the same size, wedged over a horizontal iron axle that runs above the beam the whole length of the row of mills, and turns in white beechwood bearings at the points of support. According to the position of the two rows of mills, with reference to the axle of the water-wheel (for instance, whether parallel or at right-angles to it), mitre-wheels, the same size as those on the spindles, are fixed either at one end or on some part of the length of the horizontal axles. These are simultaneously turned, at the same time moving the runners of all the mills, by two other mitre-wheels, 10 in. in diameter, with 35 teeth, that are fixed on an iron axle, connected with the axle of the water-wheel, either direct or by intermediate gearing.

The relative diameters and numbers of teeth of the large and small mitre-wheels, viz. 10 : 6 and 35 : 21, are so calculated that if the water-wheel goes at its fullest suitable speed—i. e. at 15 revolutions per minute—the runners of the mills revolve 25 times during the same period. Their general speed is, however, only 16 to 20 revolutions per minute, and the motive-power required for one mill is but 0·04 H.P., or 25 mills can be turned by 1 H.P. When the runners of a set of mills are properly arranged, so that they revolve exactly vertical and central in the basins, each of the latter receives 50 lb. of mercury (the mills of some establishments receive only 30 lb., the reason for which will be given further on), which forms a ring, 7 in. wide and ½ in. thick, at the bottom, round the central pipe; and then a most important adjustment has to be made, namely, that of raising or lowering each runner, so that the lower edges of the iron blades, projecting from its bottom, stand just $\frac{1}{2}$ line above the level of the mercury. This distance, together with the breadth of the blades ($\frac{3}{4}$ in., as above given), has, by experience, been ascertained to ensure the greatest saving of gold and smallest loss of mercury. If once in proper working order, a set of mills requires afterwards but little supervision. Small tin gutters, attached to the main launder, distribute the crushed material equally to the mills, forming the first or upper row, and introduce it into the large funnel-shaped cavity of the runners, where it descends through the open space round the central pipe, and comes into contact with the mercury. It then undergoes much whirling about through the action of the iron blades—which, while promoting contact with the mercury, prevents deposition,—and, gradually rising in the annular space between the runner and the inner wall of the basin, it passes out through the outlet spout into the mill straight in front, where the same process is repeated. The crushed material which passes a gold-mill in this manner, from a battery of 3 heavy stampers, amounts in the average, per second, to 0·015 cub. ft., containing $\frac{1}{2}$ to $\frac{3}{4}$ oz. of sand and slimes.

On account of the ores being very poor in gold, and in order not to lose unnecessary time and money by too frequent interruptions of the process, the mills are allowed to run for 4 weeks at a stretch; the runners are then lifted out of the basins, and the whole of the mercury is removed. During this work, which generally lasts several hours, any small defects of the machinery are repaired, and all the different parts properly looked after. The amalgam is pressed through specially constructed double filters of chamois leather or strong close canvas, and the filtered portion, that still contains about $\frac{5}{8}$ oz. of gold per cwt., is returned to the mills, which are then set in action again. The mills of the lower rows are generally supplied with distilled mercury, for reasons which will be explained further on. The rather soft amalgam, obtained in the filters, is repeatedly pressed through close canvas, with hot water, till it becomes quite hard, when it is formed into balls of $3\frac{1}{2}$ to 4 oz. in weight, which are labelled and reserved for distillation. This amalgam contains about 25 to 33 per cent. of gold, and the relative quantities received from the upper and lower rows of mills are, on the average, in the proportion of 64·5 per cent. : 35·5 per cent.

When the mills at the end of a working period are opened, the greater part of the amalgam is always found collected round the central pipes of the basins. This fact led to the experiment of using smaller basins, in which the ring of mercury, instead of 7 in., was only 3 in. broad, reducing the quantity of mercury to be used from 50 lb. to 26 or 28 lb. If this experiment had been generally successful, it would not only have lessened the outlay for mercury considerably, but would also in a great measure have reduced the loss of that metal; it was, however, found that from ores rich in galena—and they form by far the greater portion in Hungary—the produce of gold was 20 to 25 per cent. less than formerly. Only the ores of one mine—the Max shaft, on the Spitaler lode—which are comparatively poor in galena, yielded the same quantity of gold, whilst the loss of mercury was 50 per cent. less than previously, and they are therefore the only ones treated in small basins, supplied with but 30 lb. of mercury. The average loss of mercury sustained by the mill process is stated to be 20 oz. for 50 tons of ore rich in galena, and only $8\frac{1}{2}$ to 9 oz. for the same quantity of ore from the mine just mentioned. It is in reality, however, nearly 20 per cent. greater, for this amount is recovered during subsequent operations.

Another fact, experimentally discovered, touching the mercury and its use, as applied to the mill process, deserves mention: It is, that pure distilled mercury seizes upon gold eagerly up to a certain point—the limit of saturation—which is $3\frac{3}{4}$ oz. per 5 cwt.; beyond that point, when pasty amalgam commences to form, its action upon the gold is far less energetic. Taking advantage of this fact, by supplying the mills of both the upper and lower rows with pure mercury, and leaving it only in action till it had acquired the above limit of saturation, the yield of gold augmented 20 per cent., which, taking into account the smaller amount extracted by the subsequent operations, represented still 6·44 per cent. increase on the total produce of gold. This profit, considerable as it appears, was, however, much lessened by the expense and loss incident upon the repeated distilling of the mercury, its transport, and the more frequent interruptions of the process—the mills of the upper rows, for instance, having to be cleared every 5 to 6 days. This caused a less yearly produce, with a greater amount of manual labour, and therefore this method of amalgamation has been discontinued as far as regards the mills of the upper rows, but is still in operation for those of the lower ones, because the stuff travelling through them is so much poorer in gold that the limit of saturation of the mercury is only reached after every 28 to 30 days, when the mills of the upper rows have to be cleared also.

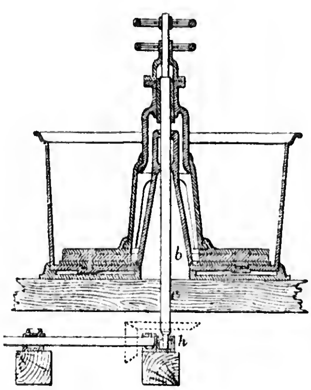
Hunter's rubber.—This machine is thus described by Thureau. It is rather complicated, combining, like most other American gold-saving appliances, two or three different actions, viz. grinding, amalgamation, and concentration. It has a similar appearance to the old shaking-tables, and its motion is also similar; but in detail it differs materially from the former. From the well stayed frame-work depend two bearers, by means of 4 bars of round iron, and these are rocked 50 times a minute by 2 excentrics and pulleys, with a stroke of 5 to 7 in. Six pieces of pine-wood are bolted to the bearers longitudinally, their tops being round and the bottom square, where they are armed at the bottom with the same number of shoes, all these being the really movable parts of the machine. In a strong cast-iron box a false bottom is laid by means of alternate strips of wood and cast-iron dies, in the same longitudinal fashion, so that the shoes rub upon the dies and thereby grind the ores. At the same time the tops of the wooden strips are covered with electro-copper plates, "and as they are immersed, any, in fact nearly all the float gold liberated by the grinding is collected at the apex of each cylindrical copper plate, and the pyrites are also concentrated in this box. This is a very valuable machine, as it collects from 10 to 12 per cent. of gold that would otherwise float away with the blue slimy water, which it is well known is allowed to escape elsewhere."

Jordan's pan.—In Jordan's "hydraulic amalgamator," the pulp leaving the battery is washed over the blankets with a sufficient quantity of water to carry it into the receiving hopper of the amalgamator, where it meets a further regulated supply of water, made to whirl round the inside of the hopper, and thus avoid all possibility of lodgment, passing thence down the stand-pipe into the pan. This is formed of two parts, the outer being a cast-iron pan containing about 3 cwt. of mercury, and the inner pan or muller, which is fixed to the stand-pipe, and revolves slowly in the mercury, being immersed in it to about an inch below the surface of the bottom. The pulp, passing down the stand-pipe under pressure of the column, is forced between the bottom surface of the muller and the mercury, and, being spread out in a thin layer, is brought into intimate contact with the latter.

McCone's pan.—This pan, Fig. 156, is 5 ft. in diameter and 28 in. deep. It is flat-bottomed, and made either with or without a steam-chamber. When the latter is desired, the false bottom is cast separately, with a rim 1 in. deep, and is then bolted to the main pan-bottom, thus forming the chamber. There are no standards or legs for the pan to stand upon, the bottom being a square-cornered plate of iron, projecting beyond the pan-rim, and it may be bolted directly to the timbers on which it is to rest. The bottom, with its central hollow cone, may be cast in one piece with the pan-rim, or, instead of the latter, a simple flange may be cast, corresponding in size with the rim, to which flange the rim, which may then be either a cast piece or be made of sheets of iron riveted together, is bolted.

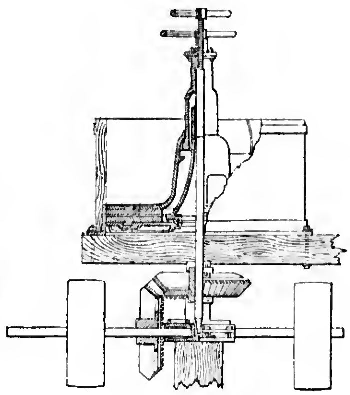
An improvement has lately been made to save the wear of the rim or side of the pan, and prolong its usefulness, by placing in the bottom of the pan a false rim or circular facing for the pan-side, about 9 in. deep. This is cast in segments, and made to correspond in form to the rim of the pan. When fixed in place, it saves the pan-rim from wear in that part which would otherwise suffer the greatest degree of friction, just as the shoes and dies protect the pan-bottom and muller-plate. When worn thin by the friction of the pulp, the plates may be removed and new ones substituted for them. The driving shaft or spindle *c* passes up from below through the central hollow cone *b*; but its point of support is usually independent of the pan, resting, in such case, in a step-box *h*, which is fixed on a timber below. Some, however, prefer to have hangers bolted to the bottom of the pan, and furnishing the support for the driving shaft, so that, if the foundations of the pan settle, the relative position of the several parts is more readily maintained. The step-box is cast in one piece, with a bearing for the end of the shaft on which the vertical mitre-wheel and pulley of the common driving gear are fixed.

FIG. 156.



McCONE'S PAN.

FIG. 157.



PATTON'S PAN.

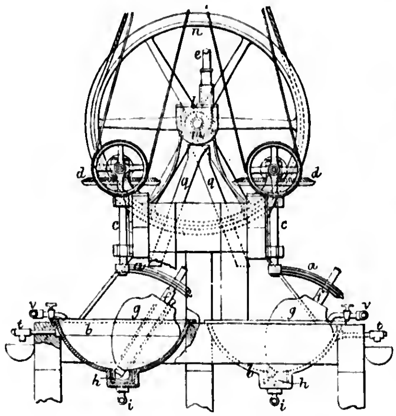
The driver or hub, which is secured to the vertical shaft, is in two parts, an upper and a lower. The upper is fixed to the shaft by two strong feathers or sliding keys. The base of the upper driver is cast with lugs, or projections, which fit into corresponding recesses in the top of the lower driver, by which means the latter is supported and set in motion. Above the upper driver is a cap-piece, carrying the usual screw and nut arrangement for raising and lowering the muller, the bottom of the screw resting on the upper end of the vertical shaft. The lower part of the driver has three or four stout lugs, or projections, at its base, which fit into carriers on the circular part of the muller. These carriers are also made to serve as the means of aiding the circulation of the pulp, as they assist in directing the current towards the centre when the muller is revolving. For this purpose, they are sometimes cast 5 or 6 in. high, presenting a curved surface, not shown in the case illustrated, to the pulp, and forcing it towards the centre of the pan. By this means, the guide-plates or wings, usually fixed to the side of the pan, but which to some extent obstruct the motion of the pulp, are dispensed with. Grooves for attaching guide-plates, are, however, cast in the pan-rim, so that those who prefer may use them. The dies and shoes used in this pan resemble, in many respects, those of other pans. There is 1½ in. space between the outer edge of the die and the edge of the pan, and a similar space between the adjacent edges of the dies. The shoes, between which are similar spaces, and which also have radial channels or grooves on their under side, to facilitate circulation, have the same radial width as the dies. The radial width of the muller-plate is a little less than that of the shoe and die, in order to allow a freer inlet and outlet to the pulp. The muller makes 60 to 80 revolutions per minute. The pan takes 4500 lb. of pulp at an ordinary charge, and sometimes more. It is set up very simply, being bolted to timber supports below, and is put in motion or arrested by the application or withdrawal of a tightener to the driving belt.

Patton's pan.—In Patton's pan, Fig. 157, the wooden sides are vertical, and the staves are held by a strong iron hoop upon an iron flange or shoulder of the bed-plate, which rises inside the pan as high as the top of the muller. The bottom is cast in one piece, and is provided with a chamber beneath for the admission of steam to heat the pulp, and thereby promote amalgamation. The pan is 5 ft. in diameter and 2 ft. deep. The motion of the muller is communicated to it from below. The distance between the grinding-surfaces is regulated by a screw on the top of the vertical shaft.

Peck's amalgamator.—The novelty in Peck's amalgamator consists in having the pans made of copper and amalgamated prior to use, the pans being arranged in a descending series, and driven by a mechanical arrangement which produces a vibratory motion in addition to the usual rotary one.

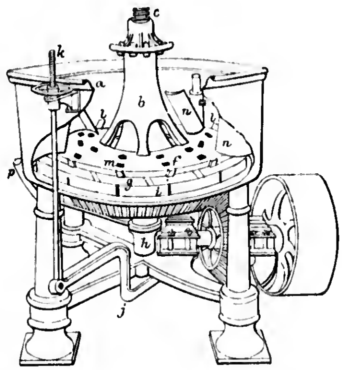
Readwin's amalgamator.—In the amalgamator recently introduced by Thomas Alison Readwin, so long known in connection with the Welsh gold industry, a framing, Fig. 158, supports the pans *b*; *c* are vertical shafts driven by gearing *d* from the driving shaft, the gearing being disconnected when required by shifting the pinion out of gear along the shaft by means of levers. The shafts *c* carry each a hooked arm *a*, in which freely rests the axis or spindle *f* of the pestle *g*, so as to carry the pestle round, at the same time allowing it to rotate about its axis, the half vertical section of the pan approaching approximately the rounded surface of the pestle. The bearings of the vertical shafts *c* are formed of hard wood, prepared asbestos, or other material which will wear well when lubricated with water. The lubricant is supplied to the bearings through holes formed in the bosses of the large gear wheels *d*. The pestle-axis *f*, which is made of hardened steel or phosphor-bronze, is fitted to the pestle-body so as to be easily removable, and so that the pestle-body can be shifted lengthwise of it at pleasure. The bottom of each pan is recessed so as to receive a hardened steel or phosphor-bronze cup *h*, in which works the lower end of the pestle-axis, and which holds the mercury for amalgamating the gold. Eyed tap-screws *i* are screwed into the bottom of the pans to allow of the mercury or amalgam being run off. A wire or bar is passed through the eyes of the screws *i*, and secured by a lock and key, so as to prevent unauthorized withdrawal of the contents of any of the pans. A trough *l*, carried above

FIG. 158.



READWIN'S AMALGAMATOR.

FIG. 159.



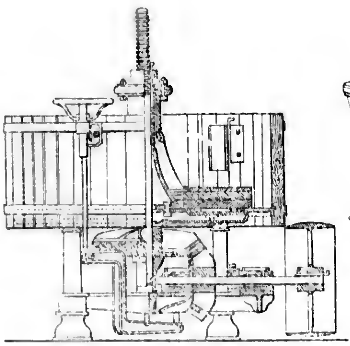
WHEELER'S PAN.

the pans, has a screw-bladed shaft *m*, which revolves by means of the wheels *n*, driven from the shaft *o*, which screw feeds the crushed ore fed from the hopper to each of the pans by means of shoots or spouts *q*. The regulating tube *e* is capable of being shifted up or down, so as to regulate the supply of crushed ore to the trough *l*. Sliding shutters, fitted to the bottom of the trough, regulate the openings so as to allow the requisite quantity of ore to pass through in a given time. An overflow pipe carries off the superfluous ore as it collects at the farther end of the trough, whence it is returned to the feed-hopper. Overflow pipes *t* allow the surplus water, together with the baser metals and gangue in a finely-divided condition, to escape from the pans by troughs to receivers. Two or more outlets may be applied to each pan when required at different levels. Pipes *v* running the length of the pans supply water.

The operation of the machine is as follows:—The cups *h* are filled with mercury. Water is then run into the pans up to the level of the outlets *t*. The pestles are then set in motion by throwing the bevel-wheels *d* into gear. The hopper being filled with ore crushed to the required size, the ore falls into the trough *l* at such a rate as may be allowed by the adjustment of the shutters of the shoot *e*. The screw *m* being set in motion carries the ore along the trough, and causes it to pass in a uniform layer over the adjustable apertures, the screw being so connected with the shaft that it shall revolve at a proportionate rate with the pestles, supplying the necessary quantity of ore per minute to each of the pans. The ore will thus be supplied gradually and in the proper quantities to the pans, and by the crushing and grinding action of the pestles on the pans it will be reduced to a finely divided condition, in which state it is presented to the mercury in the cups *h*. The mercury catches the amalgamable portion of the precious metals contained in the pulverized ore, and thus forms the required amalgam. During the process, the water, together with the baser metals and gangue, is continually flowing through the overflow pipes *t*. When it is required to withdraw the mercury and amalgam, the wire rope or rod is withdrawn from the eyes of the tap-screws *i*, and the mercury and amalgam are run off as required.

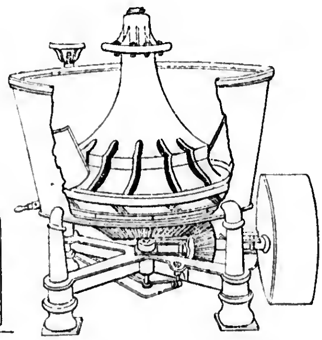
Wheeler's pan.—The Wheeler pan of ordinary size, Fig. 159, is about 4 ft. in diameter at the bottom, and 2 ft., or a little more, in depth. *a* is the rim of the pan, in the centre of which is the hollow cone *b* rising from the bottom, with which it is cast in one piece. Through this cone passes the vertical shaft, which, being driven by the gearing below the pan, gives motion to the muller by means of a driver keyed to the shaft. The muller is provided, on its under-side, with shoes *g* that form the upper grinding surface. They are attached to the muller by means of two lugs or projections *f*, which are received in corresponding apertures in the muller-plate, and securely wedged with pieces of wood. The lower grinding surface is formed by the dies *i*, which are usually 4 or 8 in number, covering the greater portion of the pan-bottom, and secured to it in a manner similar to that by which the shoes are fixed to the muller. There is a radial slot or space between the dies, which is commonly filled with hard wood. Below the bottom is a steam-chamber for heating the pulp. The vertical shaft or spindle rests in a step-box *h*, to which oil is conveyed by the pipe *p*. A vertical pin passes downward through the centre of the step-box, in contact with the shaft and resting its lower end on the lever *j*. This lever may be raised or lowered slightly by the hand-wheel on the rod *k*, thus raising the muller from the dies, if desired. The shaft is also furnished with a screw *c*, by means of which the muller may be raised up entirely above the rim of the pan for the purpose of cleaning up or of changing the shoes and dies. In order to impart an upward current or movement to the pulp, there are inclined ledges *l* on the rim of the pan, and smaller ledges *m* on the periphery of the muller, but inclined in the opposite direction. The pan is also provided with wings or guide-plates *n*, 4 in number, which serve to direct the moving pulp toward the centre. They are fitted into and may be removed at pleasure from a T projection on the pan-rim. The muller is usually caused to make about 60 revolutions a minute; it requires $2\frac{1}{2}$ to 3 H.P. Its ordinary charge is 800 to 1000 lb. In some mills, a still larger charge is worked. The capacity of the pan is sometimes augmented by adding a rim of sheet iron, so as to increase the height of the side. The treatment of the charge usually requires 4 hours. The shoes and dies wear out in 3 to 6 weeks, though they are made to last longer in some mills, their duration depending greatly upon the order in which the pan and all its principal working parts are kept. Neglect in oiling the working parts of the running gear is apt to cause unequal wear, the vertical shaft gets loose and out of line, the grinding-surfaces cease to work together evenly, and the efficiency of the pan is greatly impaired, while the costs of working are very much increased. Mill-men generally prefer a shoe and die of moderate rather than excessive hardness. The former wear out faster, but are thought to grind more efficiently. Such are usually cast of an equal mixture of white and soft iron.

FIG. 160.



WHEELER'S PAN.

FIG. 161.



WHEELER & RANDALL'S PAN.

A more modern form of Wheeler's pan is shown in Fig. 160. It bears considerable resemblance to Patton's, already described (p. 1048).

Wheeler & Randall's pan. — Fig. 161 presents a view of the "excelsior" pan, devised by Wheeler & Randall. It differs from others chiefly in the form of the bottom, which is conoidal. The object of this device is to produce surfaces of such form as to ensure perfect uniformity of wear and the highest degree of grinding effect. Its efficiency, in this respect, is attested by the experience of practical mill-men. It is not, however, so generally used as the ordinary Wheeler.

The dies, muller, and shoes, have a form corresponding to that of the pan-bottom. They are secured in place in much the same way as in the Wheeler pan. There are guide-plates to assist in directing the movement of the pulp, and openings in the muller between the shoes for its free passage between the grinding surfaces. The gearing of the pan, step-box, and driving-shaft, and means of raising the muller, do not differ materially from the common Wheeler pan. This pan is made of various sizes; the largest is $4\frac{1}{2}$ ft. in diameter, and treats 3000 lb. of ore at a single charge. It weighs 5000 lb.

Blanket-tables.—In Hungary, Victoria, and some parts of America, the matters leaving the last row of pans or bowls fall into a narrow trough, from which, by means of wooden shutters, they are equally distributed over a number of inclined tables or "strakes" clothed with blanketing or canvas. When no pans or bowls are used, the tables immediately succeed the battery.

The Victorian form consists of a wooden floor, with varying length, and laid at a varying pitch or incline. It is fixed securely, and in such a manner as will enable the pitch to be altered, always observing the utmost regularity in its arrangement, and ensuring precisely the same degree of pitch throughout the entire length. The surface of the table is made perfectly smooth and true. By means of strips of wood $2\frac{1}{2}$ in. wide fastened to the floor, it is subdivided into "strakes," one for each stamp in the battery, when pans or bowls are not employed; these strips afford a place for the man to step on who changes the blankets. Sometimes the table is broken transversely into sections of 3 ft. or so, the upper edge of each section being about 2 in. below the overlapping edge of the one next above. The surface is covered throughout with closely-woven baize or blanket, laid on with extreme care, so as to lie flat and cling to the boards. The mixture of water, mercury, and disintegrated matters passes over the surface of the blanketing in a thin stream. The high specific gravity of the gold and pyrites causes them to descend to the lowest stratum of this stream, by which they are brought into contact with the fibres of the blanketing, and are induced to settle among them. From these they are subsequently dislodged by rolling up the blankets in turn and washing them in clean water.

The Hungarian apparatus differs in that it is made even throughout (without any steps), and that the covering medium is a very rough kind of canvas, resembling sackcloth, and specially prepared for the purpose. The length and breadth of the tables vary in different establishments from 6 to 12 ft. and from 13 to 18 in. respectively, with an inclination of 1 to $1\frac{1}{2}$ in. per ft.; they are constructed by preparing an even flooring of boards, laid crossways, of the required size and inclination. This is divided into equal spaces by longitudinal partitions, 2 to 3 in. broad and 2 in. high, with cheeks of similar dimensions fixed along the sides. The number of strakes constructed in connection with a certain number of mills is usually in the relation of 6:8, with one table extra. Thus 8 mills have 7 tables, 6 of which are in action at a time, whilst the 7th is opened when 1 of the 6 is closed for the purpose of washing the canvas pieces. These pieces are generally cut of such a size that 2, for instance, cover a table 6 ft. in length, including the overlap. Numerous experiments have proved this coarse canvas, partly as regards cheapness and partly in efficiency, to be better than either blanketing or two other peculiar methods of producing the required rough surface, viz. (1) by scratching the boards, and (2) replacing the latter by finely corrugated iron plates. The wear and tear of the cloth, which is prepared of a width to suit that of the tables, is about 16 ft. for working 50 tons of matter, the pieces lasting generally 6 to 8 weeks. They are washed in tanks, in the same manner as the blanket-pieces used in Victoria. The operation is performed by boys, every 1 to 3 hours, according as the supply of material is greater or smaller, one boy commonly sufficing to work 10 or 15 tables. The stuff collected in this manner in the washing-tanks forms 2 to 3 per cent. of the whole amount of ore crushed, and consists (in Hungary) of finely-divided galena, pyrites, and gangue, through which are distributed fine free gold and small globules of mercury, escaped from the mills.

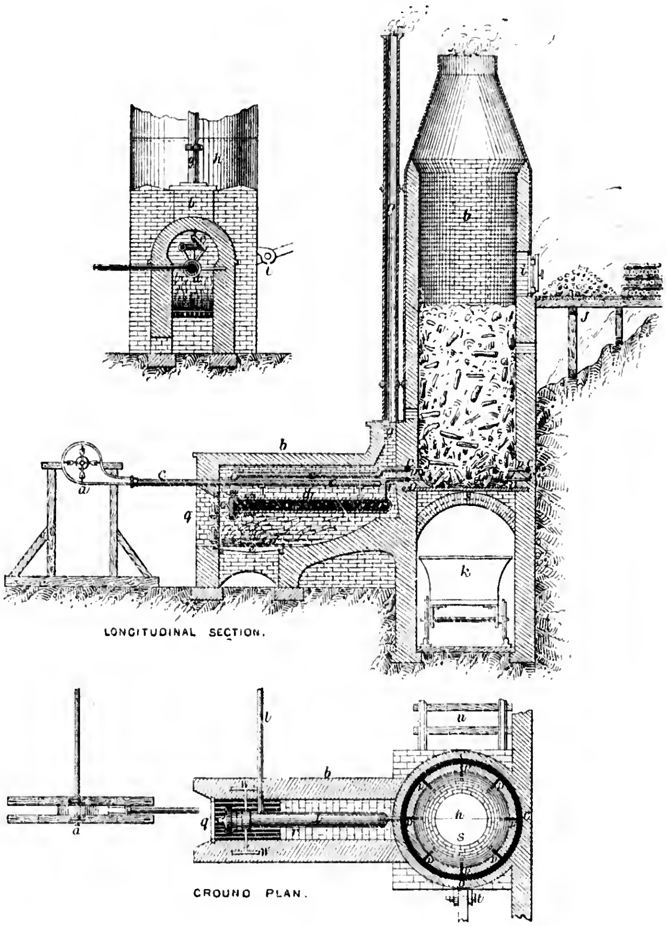
Many conditions govern the success or failure of the blanket-table. (1) When the gold is stamped to an excessive degree of fineness, or is flattened into tiny thin plates, it becomes what is known as "float" gold, i.e., owing to the minuteness of the particles, or their flattened shape, other forces tend to counterbalance the effect of their great specific gravity, and instead of sinking as usual they actually float away. (2) The supply of water must be exactly adapted to the nature of the material under treatment: if too little, the material will be unevenly distributed, and will clog the blankets; if too great, it will wash away some of the gold. (3) Too rapid inclination of the tables is often a source of loss: it should scarcely ever be greater than 1 in 14 to 16. (4) The length of the table is of importance in reducing the inevitable loss to a minimum; for, though by far the largest proportion of the valuable matters is deposited on the first few ft. of the strakes, yet, however far the latter may have been continued, they will always catch some particles. In practice, it would be inconvenient to much exceed 30 ft., but 20 ft. should be regarded as a minimum figure. (5) The interstices of the blanketing would, in course of time, become choked with heavy matters, and would then cease to be a receptacle. The washing and renewing must therefore be performed at sufficiently short intervals. The frequency with which this is repeated will much depend upon the character of the material, being increased when it is "slimy," and when much pyrites is present. The first series of blankets may need changing every hour, or even oftener; the second, every 2 hours or so; and the remainder, every 6 to 12 hours. Much gold is lost through slovenliness in this department. (6) Sufficient care is not generally exercised in the selection of the fibrous material used for covering the strakes; and experiments with various kinds of hair and wool, and with different classes of fabric, may be expected to throw considerable light upon the subject.

Roasting.—The idea of roasting quartz before crushing was probably borrowed from the habits of aboriginal natives in many parts of the world, of burning rocks to facilitate their grinding in the imperfect appliances at hand. The plan first adopted by Australian miners was to roast the quartz in stacks in the open air, or in kilns, to oxidize the sulphides, and so liberate the gold, while the quartz was rendered more friable and easy to crush. After several years' trial, this system was given up, as it was found to be rather injurious than otherwise. At a low heat, the pyrites in the interior of the quartz was little changed, while the free gold was coated with a film of some material, probably sulphur, which impeded the action of the mercury on it. When the roasting was carried on with a higher degree of heat, the oxide of iron formed on the exposed faces of the quartz acted as a flux, and a glazed surface of slag was formed, in which numerous minute globules of gold could be discerned under the microscope, similar to those found in the waste tailings when crushing roasted quartz. In the interior of the quartz only a portion of the sulphur was given off, while black veins were formed by the melted mono-sulphide of iron; and other experiments led to the conclusion that a portion of the melted gold was diffused through these black veins in a form which rendered it more difficult to separate than when in its natural state.

But these objections do not apply to the roasting of quartz which is free from pyrites, and Wilkinson, as early as 1861, established a furnace (Fig. 162) at Anderson's Creek, Victoria, for this purpose; this was the subject of a report, which may be summarized as follows.

The quartz subjected to this peculiar calcination is exceedingly friable, much more so than the best roasted quartz from open kilns. That whose treatment was witnessed by the Board was very crystalline and compact, and each piece of it after coming from the furnace could easily be broken by the hand, in every direction, into small fragments. From the experiments made with a view of referring this important change in the hardness of the quartz to its legitimate cause, it seems to be mainly attributable to the high temperature (a moderate white heat) to which the quartz was subjected in the furnace. Wilkinson does not attach much importance to suddenly cooling, or quenching the heated

FIG. 162.



WILKINSON'S QUARTZ FURNACE.

quartz with water; but the Board are of opinion that a difference does exist in favour of quartz thus treated over that which has been cooled slowly: this difference is greatest when the quartz is only heated to a dull-red, and becomes less marked when a bright-red or white heat is attained. It would also appear that the increased friability from this cause is due more to the explosive force of the steam than to the sudden change of temperature, for it should be borne in mind that it is difficult, if not impossible, to effect the sudden cooling of masses of broken quartz on the large scale, even when the quantity of water available is very great, for the steam first generated forces the water from the interstices between the pieces of stone, preventing actual contact, so that the cooling is in reality much more gradual than it would at first sight appear to be.

The benefits to be derived from the friability of the quartz after calcination are very evident: much lighter stamps will suffice to reduce it than when the same is in a raw or imperfectly roasted condition. It is also obvious that grinding machinery of every kind will perform its office more efficiently and perfectly.

The high temperature obtained by Wilkinson gives rise to another phenomenon of equal or greater value, influencing more materially the ultimate result, viz., the change in the form of the auriferous particles. A close examination of the fine gold extracted after calcination has proved that it is all globular in form, or approximately so, and that the more minute the metallic particles are the more perfect is their spherical shape.* That this should be the case will not appear surprising, when it is remembered that the temperature to which the gold is heated is far above that necessary to effect its fusion, and that, being melted, the molecular attraction between its atoms must determine the spherical form, subject to the constraining influence exerted by the rigid material in which it is embedded. While the metallic particles diffused throughout the quartz are undergoing this change *in situ*, the heat also tends to diminish the cohesion which gives the quartz its hardness, to expand its mass, and to open the fissures in which the greater part of the gold is doubtless deposited, thereby aiding the desirable change, inasmuch as it lessens the constraining influences above referred to.

The Board are convinced that this change from the jagged or laminated form to the smooth and globular, must exert a very beneficial influence upon subsequent washing and amalgamating operations, more particularly in preventing a loss of fine gold, for as a particle in the spheroidal form is contained within the least possible surface, it is plain that it will be less acted upon by moving water, or by mixtures of water and pulverized mineral matter, than when it is in a thin leafy or any other attenuated form. The gold will, therefore, sink more readily to the mercury, whereby a saving in time will be effected, and its amalgamation will be rendered more certain and perfect. At the same time, it should

* A similar change in the form of gold, but to a very limited extent, affecting more particularly the larger particles, has been observed in gold from quartz roasted in the ordinary way.

not be forgotten that the rounded particles will roll on hard and sloping surfaces, and modifications of some of the means in common use to prevent their escape may be found necessary.

The experiments made upon the gases used by Wilkinson demonstrate that when, as in his process, vapour of water is passed over red hot charcoal in excess, enclosed in a retort or large tube, two gases only are the ultimate result, namely, hydrogen and carbonic oxide; they have also shown that a dull-red heat is sufficient to effect the decomposition of the water, although the charcoal may be made much hotter with advantage. The manner in which the chemical changes take place is, probably, as follows :—The incandescent charcoal meeting with the steam effects the decomposition of the same by combining with its oxygen, forming carbonic acid gas, and setting its hydrogen free; the former of these gases is still further acted on by the large excess of charcoal present, it parts with half its oxygen to a fresh portion of carbon and gives rise to carbonic oxide; these two gases are remarkable for the heating powers they possess when subjected to combustion, more especially when, as in Wilkinson's furnace, a hot blast is used; they are in consequence well adapted for producing a very intense heat without the introduction of a large quantity of bulky fuel, and in a very short time. The following items have been calculated with a view of placing the circumstances under which these two gases are formed in a clearer light :—

One hundred parts of water by weight require 66·6 parts of charcoal to effect its complete decomposition and the production of the gases. The two gases are produced in equal volumes, weighing together 166·6 parts, while of this mixture 155·5 parts by weight are carbonic oxide, and 11·1 parts hydrogen—or, in other words, 1 lb. avoirdupois of water (equivalent to about 28 cub. ft. of steam at 212° F.) will consume 10·65 oz. avoirdupois of charcoal, and generate 42 cub. ft. of the mixed gases, supposing the same to be cooled to the ordinary temperature of the air: so far, however, from being cooled, the gases enter the furnace at a very elevated temperature, and therefore much increased in bulk; and there meeting with the heated atmospheric air, all the conditions for rapid combustion are established, while the heat is applied in a manner calculated to permeate the closely-packed quartz. There can be no doubt that a large portion of the heat in the furnace at Anderson's Creek was obtained from the solid fuel (wood and charcoal) directly introduced; but the Board are of opinion that one half of this might have been saved by better management of the furnace and with more perfect mechanical arrangements for supplying the gases and blast.

It is probable that, besides acting as fuel, these gases play an important part as chemical agents in relation to the gold and other contents of the quartz, such as the metallic sulphides, arsenides, oxides, &c. Iron-pyrites, for instance, is reduced to metallic iron, strongly magnetic and containing but a small quantity of sulphur, an effect which could never be produced in an ordinary furnace charged with charcoal and supplied with a hot blast alone. In this case, there can be little doubt that the hydrogen is the active agent, and that its reducing power is greatest when, towards the close of the calcination, the admission of air is stopped, and the gases are still allowed to play upon the quartz. The metallic iron thus produced is, like the gold, found to assume the globular form; the specimens of it which the Board had assayed were shown to contain gold in considerable quantities (in one case 0·03, and in another 0·07 per cent.), but whether more or less than the pyrites from which it was derived it is not possible to say.

Wilkinson claims for his process the credit of obviating the difficulty caused by the presence of sulphides with the gold: how far a further investigation of the peculiar reducing action of the hydrogen may tend to throw light upon this subject, the Board are not in a position to state; but they do not think that Wilkinson can at present be said to have been practically successful in working out this particular point, for although in the case of iron-pyrites the sulphur has been almost completely expelled, still a certain proportion of gold is left in combination with the iron, and separate treatment will be necessary for its extraction. On theoretical grounds, the Board believe that an investigation of the effects produced by the mixed gases on arsenical pyrites, sulphide of lead (galena), and sulphide of antimony—minerals which interfere materially with the economical treatment of auriferous quartz—would lead to results of the greatest importance.

As far as the amalgamation is concerned, the Board are convinced that an imperfect roasting of the quartz, such as that commonly practised, is almost invariably detrimental. On the other hand, they are distinctly of opinion that the very high temperature obtained in Wilkinson's furnace would entirely prevent the coating of the gold with sulphur, arsenic, or other volatile matters, and that even if a deposit did exist, the action of the unburned hydrogen in the latter part of the process, would, in most cases, tend to remove it, whereby the gold would be sent to the mercury with a pure metallic surface. In this respect, Wilkinson's process is a very great improvement on those in which the ordinary roasting is employed. An extract of a letter from Thompson of Clunes, annexed, contains some positive information bearing upon this subject.

The question of cost, as far as the calcination is concerned, has been discussed by comparing that incurred at Anderson's Creek, with that of burning quartz in open kilns of 100 tons capacity at the Port Phillip and Colonial Gold Mining Co.'s works at Clunes.

The following table will show the result obtained—

	Quantity of fuel per ton of quartz.		Cost of fuel.		Cost of labour per ton, charging and discharging.	Total cost.
	Wood.	Charcoal.	Wood.	Charcoal.		
	lb.	lb.	*s.* *d.*	*s.* *d.*	*s.* *d.*	*s.* *d.*
Anderson's Creek	455	84	0 9¾	2 1¼	2 8	5 7
Clunes	280	..	1 3	..	2 8	3 11

In this table, the quantities of fuel are necessarily given by weight for both localities, they must only be taken as approximate, as the weight of a ton measurement or cord of wood will vary in proportion as it is dry or wet, while charcoal becomes much heavier on exposure to the air. The heating power or efficiency of fuel will also depend on these circumstances; the prices given are those which rule in each locality; the cost of the gases used by Wilkinson has not been added, because it could not be estimated with any pretension to accuracy, and because the Board were convinced, that in the calcination they witnessed, it formed an inconsiderable item, the omission of which would not cause an important error. The cost of labour has been assumed to be the same in both cases. The Board have already stated their belief that half at least of the fuel introduced directly into the furnace might be saved by more perfect arrangements, and by calcining larger quantities at a time. They regard the solid fuel only as an accessory means of heating the quartz in the first instance, until the gases are properly ignited, and are convinced that for this purpose the charcoal might be altogether dispensed with, and that therefore the cost of Wilkinson's calcination might be considerably reduced.

The quantity of quartz operated upon was 1600 lb. weight; it was very hard and crystalline, free from clay and "mullock," and was broken to about a 4-in. gauge. Only a speck or two of gold was discernible as it lay in the heap. The fuel used was 325 lb. of wood (peppermint and stringy-bark gum, tolerably dry) and 60 lb. of charcoal. Charging commenced in a cold furnace at 6 h. 30 m., a.m., and was completed at 7 h. 17 m. A good heat was then got up by the fan, and steam to the retort was turned on at 8 h. 15 m.; at 8 h. 50 m. the gases were shut off, the blast having been stopped about 10 minutes previously. The contents of the furnace having by this time obtained a moderate white or a very bright-red heat, they were allowed to fall, by opening a trap-door at the bottom of the furnace, into an iron tank, on wheels, placed to receive them; in this waggon they were rolled to the crushing floor, and were quenched with water by playing upon them with a hose. The quartz now presented the appearance of having been broken to a 2-in.

gauge; the pieces were much blackened on the surface, and were very friable.

The various parts are as follows:—*a*, air-fan for hot blast; *b*, furnace for hot blast and the gases; *c*, generating and conducting pipes of hot blast; *d*, retort to generate the hydrogen and carbonic oxide gases; *e*, fire-bars; *f*, conducting pipe of the gases; *g*, chimney of gas-furnace; *h*, roasting-furnace for quartz; *i*, door for charging roasting-furnace; *j*, platform for quartz and fuel; *k*, truck for conveyance of calcined quartz; *l*, steam-pipe conveying steam to gas-retort; *o*, nozzles by which the gases enter the roasting-furnace; *p*, nozzles by which the hot blast enters the roasting-furnace; *q*, door of hot blast and gas furnace; *r*, fire for production of hot blast and gases; *s*, cast-iron bottom plate of roasting-furnace; *t*, fulcrum of lever; *u*, tramway for conveyance of calcined quartz; *w*, cast-iron support of gas-retort. A lever and windlass for opening and closing the bottom of the furnace are not shown.

TREATMENT OF BLANKET-SAND.

Barrel-amalgamation.—The material gathered from the blanket-strakes, consisting of grains of free gold, globules of mercury, and particles of amalgam, which have been splashed or washed from the troughs, ripples, or plates, with a large quantity of pyrites, and some worthless matter, is collectively termed "blanket-sand." It is usually treated with mercury in a revolving barrel, the process being known as "barrel-amalgamation."

When the proportion of free gold is considerable, and the operation is properly conducted, it gives most satisfactory results. The barrels are of wood or iron, and are constructed to revolve on a pivot at each end. The charge is 8 to 10 cwt. of the damp blanket-sand, and 200 to 300 lb. of mercury. The charged barrel is set to revolve for about 8 hours, at a speed of 14 to 16 revolutions a minute. After this, it is filled up with hot water, and set to revolve again for another 4 hours, at a rate of 5 or 6 revolutions a minute. This concludes the operation, and the charge may then be drawn off. The free mercury and most of the amalgam are withdrawn first. The remainder of the contents is sent to a shaking-table, or some similar contrivance, for effecting the separation of the amalgam, pyrites and refuse. The two latter are treated the same as the "tailings." Stones and pieces of iron are sometimes put into the barrel, on the erroneous assumption that by grinding the sand finer they aid the amalgamation, whereas they are more likely to "sicken" the mercury by grinding the pyrites present. When the blanket-sand contains very little free gold, it is best treated like concentrated tailings, instead of by barrel-amalgamation.

TREATMENT OF THE TAILINGS.

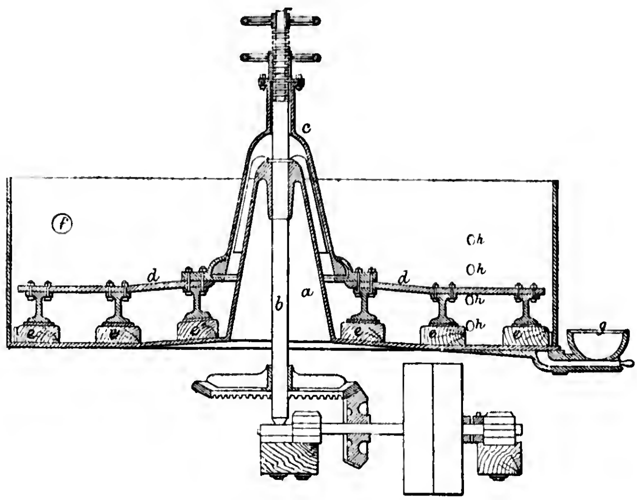
Definition and General Principles.—All the stamped material remaining beyond the portions which are caught by the blankets, plates, riffles, and troughs, is collectively known as "tailings." It consists principally of fine earthy matters, but contains also more or less of gold, amalgam, mercury, and pyrites, chiefly the last. In some instances, especially when the ore has been largely pyritous, the tailings have a very high value; in all cases, the recovery of the gold held by them demands every attention from the miner who desires to achieve success. Unfortunately, their treatment is full of difficulty, and hence the only too frequent disposition to neglect them totally or partially. It is only where the poverty of the ores renders it imperative to extract all the precious metal they contain, in order to obtain a remunerative result, that any really effective and economical plans have been devised for the purpose. When the ores are sufficiently rich to pay a good profit from the more easily extracted portion, little attention has been given to this question. Yet there can be no excuse for throwing away a quantity of gold because the mine happens to pay well without it.

The treatment of the tailings should comprise three distinct operations, known as (1) "settling," or allowing the heavy valuable matters to settle down in the mass, (2) "sizing," or classifying the matters into several grades according to the size of the grains, and (3) "concentrating," or still further separating the various materials according to their specific gravity.

The sands, pyrites, slime or slum, and water, which have escaped from the blankets and other devices and passed into the waste-trough, are sent into the "settlers," where the heaviest portions fall to the bottom. The accumulated matters are cleared out periodically, and very frequently supplied directly to a concentrator. But this is a reprehensible practice, as is evident when it is borne in mind that all methods for the mechanical concentration of ores, based upon the fact that the ore is specifically heavier than the refuse, can only fully succeed when that superior weight of the ore is most thoroughly availed of. On a previous page allusion has been made to the circumstance that the relatively greater specific gravity of the particles may lose its effect in the presence of material of disproportionate size and shape. In other words, though pyrites is very much lighter than gold, and quartz is lighter still, yet it is easy to imagine pieces of pyrites or quartz whose size may be sufficiently great to counterbalance their relative lightness. The shape of the particles is determined by the crushing operation, and cannot be subjected to control; but the classification of the grains according to size, at least within reasonable limits, is not difficult of attainment: indeed many contrivances are in use for the purpose in the concentration of such heavy ores as galena, tin-stone, &c. The value of these apparatus for treating auriferous pyrites is intensified by the fact that the gravity of the latter, as compared with that of quartz, presents far less contrast than does the gravity of lead- or tin-ore to its gangue; besides, the pyrites is so much softer and more brittle than the quartz, that it is crushed relatively much finer. For these reasons, the "sizing" of the tailings, before any attempt is made to concentrate their valuable portion, must evidently be of considerable advantage.

Settlers.—These differ somewhat in details of construction, but they usually are round tubs of iron, or of wood with cast-iron bottoms, re-

FIG. 163.



SETTLER FOR TAILINGS.

sembling the pans in general features, but larger in diameter. A hollow pillow or cone *a*, Fig. 163, is cast in the centre of the bottom, within which is an upright shaft *b*. This shaft is caused to revolve by gearing below the pan. To its upper end is attached a yoke or driver *c*, that gives revolving motion to arms *d*, extending from the centre to the circumference of the vessel. The arms carry a number of flows or stirrers, of various devices, usually terminating in blocks of hard wood *e*, that rest lightly on the bottom. No grinding is required in the operation, but a gentle stirring or agitation of the pulp is desired in order to facilitate the settling of the amalgam and mercury. The stirring apparatus, or muller, makes about 15 revolutions a minute.

The settler is usually placed directly in front of the pan, and on a lower level, so that the pan is readily discharged into it. In some mills, two pans are discharged into one settler, the operation of settling occupying 4 hours, or the time required by the pan to grind and amalgamate another charge. In other mills, the settling is allowed only two hours, and the two pans connected with any one settler are discharged alternately.

The consistency of the pulp in the settler is considerably diluted by the water used in discharging the pan, and by a further supply, which in many mills is kept up during the settling operation. In other mills, however, the pulp is brought from the pan into the settler with the addition of as little water as possible, and allowed to settle for a time by the gentle agitation of the slowly revolving muller, after which cold water is added in a constant stream. The quantity of water used, affecting the consistency of the pulp, and the speed of the stirring apparatus, are important matters in the operation of settling. Since the object of the process is to allow the mercury and amalgam to separate themselves from the pulp and settle to the bottom of the vessel, it is desirable that the consistency should be such that the lighter particles may be kept in suspension by a gentle movement, while the heavier particles fall to the bottom. If the pulp be too thick, the metal will remain suspended: if it be too thin, the sand will settle with it. Too rapid or too slow motion may produce similar results, because, by too violent motion, the mercury will not be allowed to come to rest on the bottom, while, if the motion be too slow, the coarser sand will not be kept in circulation.

A discharge-hole *f*, near the top of the settler, permits the water carrying the lighter portion of the pulp to run off; and, at successive intervals, the point of discharge is lowered by withdrawing the plugs from a series of similar holes, *h*, in the side of the settler, one below the other, so that finally the entire mass is drawn off, leaving nothing in the settler but the mercury and amalgam. There are various devices for discharging these. Usually, there is a groove or canal in the bottom of the vessel leading to a bowl *g*, from which the fluid amalgam may be dipped or allowed to run out by withdrawing the plug from the outlet pipe.

The agitators through which the pulp passes after leaving the settlers are, in general, wooden tubs, that vary in size from 6 to 12 ft. in diameter and 2 to 6 ft. in depth. The main object in letting the stream of pulp pass through them is to retain and collect as much as possible of the mercury and amalgam and heavy particles of undecomposed ore that are carried out with the pulp discharged from the settler. A simple stirring apparatus, somewhat resembling that of the settler, keeps the material in a state of gentle agitation, the revolving shaft carrying 4 arms, to which a number of staves are attached. In some mills, there are several agitators, in most cases only one, and by some they are not used at all. The stuff that accumulates on the bottom is shovelled out from time to time, usually at intervals of 3 or 4 days, and worked over in pans.

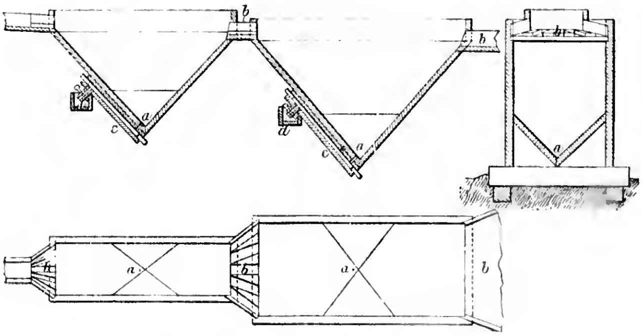
Sizers. Sieves.—Probably the most exact contrivances for classifying according to size are inclined rotating sieve-drums. In these, the material is introduced at the higher end, and passes through finer and coarser sieves in succession. But the objection to their use is that they require a considerable amount of attention, so that they are not suited for a country where labour is dear; nor have they the capacity for treating the large bulk of material which accumulates at many gold-mines. The spiral sieve introduced by Schmitt-Manderbach of Dillenburg, and sold here by A. Dick, 110, Cannon St., appears to be one of the most successful.

Labyrinths.—The slime labyrinth is a German apparatus, and is used in some Hungarian gold-mills. It consists of a number of contiguous, connected settling-pits, which, if, for instance, in connection with 3 batteries of 3 light stampers, increase in size from 1 to $1\frac{1}{4}$, $1\frac{1}{2}$, and $1\frac{3}{4}$ ft. sq. in transverse section, and respectively from 15 to 21, 24, and 36 ft. in length, with inclinations in the same sequence of $\frac{1}{2}$, $\frac{1}{4}$, and $\frac{1}{8}$ in. per foot, the largest being horizontal. Such a labyrinth classifies the stuff into 4 portions, differing in size of grain, which form deposits during the passage from the smaller to the larger pits, the coarser grains depositing in the former. This classification is, however, far from perfect, and is besides attended with expenses on account of transport and re-puddling of the settled stuff, previous to further treatment. It also entails a large loss through escape and waste of fine material, that generally amounts to 10 or 12 per cent., but may, in unfavourable cases, rise to 15 or 20 per cent. The labyrinths are therefore now in operation only in some of the older and smaller establishments, where want of space or other circumstances prevent the use of either of the other two following classifying apparatus, which, as far as experience goes, satisfy all requirements.

Pyramidal boxes.—The pyramidal boxes or *Spitzkästen* of the German gold-miners, Fig. 164, are, as their name implies, hollow, generally rectangular, pyramids. They are constructed of strong boards, well joined together (strong sheet-iron may be employed also). The sides are inclined at angles of not less than 50°, and there is a small hole in one side close to the apex. They are fixed horizontally, in an inverted position, and the crushed material is introduced at one of the narrow sides, a few inches below the top, by means of a launder. The result is that, as soon as the box is filled, a certain portion of the crushed matter—

i. e. the coarsest and heaviest, which the water, on account of its diminished velocity, is not able to carry farther—sinks and slides down the inclined sides of the pyramid, and escapes through the small hole *a* near the apex, whilst the finer and lighter matter passes off at the top by an outlet *b* in the centre of the side, opposite to the point of entrance. If now a second larger box be attached to the first, a third still larger to the second, and so on—each succeeding box at a slightly lower level, in order to prevent any settlement of stuff in the passage-ways—it follows not only that the same process of settling and escaping of the particles from the apex will take place in every box, but also that their size will decrease nearly in inverse proportion as the surface of a succeeding box is larger than that of the preceding one, or directly as the velocity of the water is diminished in it. According to this principle of the boxes—if they were made of only very gradually increasing size, and the apex

FIG. 164.



GERMAN PYRAMIDAL BOXES OR SPITZKÄSTEN.

holes proportionately small—it would be possible to classify the stuff into a great number of portions, different in size of grain, before it had entirely settled—i. e. till clear water passed off from the last box. Experience has, however, shown, that for fine ore-dressing in general, classification into 4 different sizes by an apparatus of 4 boxes is quite sufficient. The sizes of the different boxes, in order to ensure the most perfect classification, depend both on the amount of material which has to pass through them per second, and the size and character of the grains; and by theory and practice it has been found, that for the supply of every cub. ft. of material, the width of the first or smallest box must be $\frac{1}{10}$ ft.—i. e., for instance, for 20 cub. ft., 2 ft.—and for every succeeding box it ought to be about double that of the preceding one, or, generally, the widths of the boxes must increase nearly in geometrical progression, 2 : 4 : 8, &c., and their lengths in an arithmetical one, 3. 6, 9, &c.

For the stuff under notice, their dimensions are thus in different large establishments as follow :—

The first	box is	6	ft. long and	$1\frac{1}{2}$ to $1\frac{3}{4}$	ft. wide.
,, second	,,	9	,,	$2\frac{1}{2}$ to 3	,,
,, third	,,	12	,,	4 to 5	,,
,, fourth	,,	15 to 16	,,	8 to 10	,,

Their depths depend on the angle of inclination of the sides, which, as already stated, is generally 50°, because if less, the stuff would be liable to settle firmly and choke the central orifice, and if larger, unnecessarily great height of the boxes would be required. The form of the two smaller boxes is commonly such that the two short sides are inclined at the above angle, and the two long ones, which would become far steeper, are broken—i. e. are for a certain depth from the top vertical, and afterwards inclined at the normal angle. This modification has, however, no influence upon the action of the boxes, but simply facilitates somewhat their construction and firm fixing. The sides of the larger boxes are generally even throughout. The way in which the outlet-holes *a* at the apexes are constructed has an important bearing on the operation of the boxes. At these points, the hydrostatic pressure is considerable, and the holes should naturally be kept small, in order to prevent too much water passing with the particles of stuff; such small outlets are, however, especially on the treatment of coarser material, very liable to become choked. This difficulty has been met by the holes being made of conveniently large size, but connected with pipes *c*, $\frac{3}{4}$ in. in diameter, which rise up the sides of the boxes—i. e. of the smallest box to within 3 or $3\frac{1}{2}$ ft., and of the others to within 2 to $2\frac{1}{2}$ ft. from the top—and are there furnished with small mouthpieces *d*, supplied with taps for regulating the outflow. This arrangement, on account of the outlets being so much higher, has the further advantage that a considerable amount of fall is gained (especially as regards the large boxes), which, for the subsequent treatment of the material, is in some cases of special value. There are two more points that require attention, in order to ensure good action of the apparatus, namely, the introduction of the material into the different boxes equally and without splashing, and prevention of the entrance of chips of wood, gravel, or other impurities that are likely to stop or obstruct the outlets. The first point is met either by having the supply-launders expanded fan-like and furnished with dividing-ledges *b*, or by the interposition of small troughs, the sides of which nearest the box to be supplied are perforated near the bottom by equidistant, small holes. The cleaning of the material, previous to its entering the first box, is generally effected by the main supply-launder being made a little wider near the point of entrance, and the insertion at this place of a fine wire-sieve across the launder and somewhat inclined against the stream. This sieve must be occasionally looked after, to remove any impurities collected in front, and this, in fact, is the chief attention the whole apparatus requires; for otherwise it needs hardly any supervision. If once in proper working order, its action is constant and uniform, provided the material introduced does not change in amount and quality; and it has this further advantage, as compared with the slime labyrinths, that the classified stuff can, from the outlets, be directly conveyed in small launders to the concentration-machines for treatment, without any previous preparation. One point, however, not in favour of the apparatus, is that, having to be placed between the gold-mills and the concentration-machines, a great fall of ground is required, to permit the direct introduction of the material and allow sufficient fall for the tailings; and thus, where local circumstances are unfavourable, it has to be erected at a higher level, and necessitates the use of Jacob's ladders or pumps for lifting the stuff. The action of the different boxes on the material under notice with regard to the percentage of fluid matter and the quantity and character of its solid contents, which they respectively separate, is according to experiment as follows:—

The small box separates 38 to 40 per cent., containing per cub. ft., 16 to 18 lb. coarse sand.

The second box separates 20 to 22 per cent., containing per cub. ft., 13 to 14 lb. fine sand.

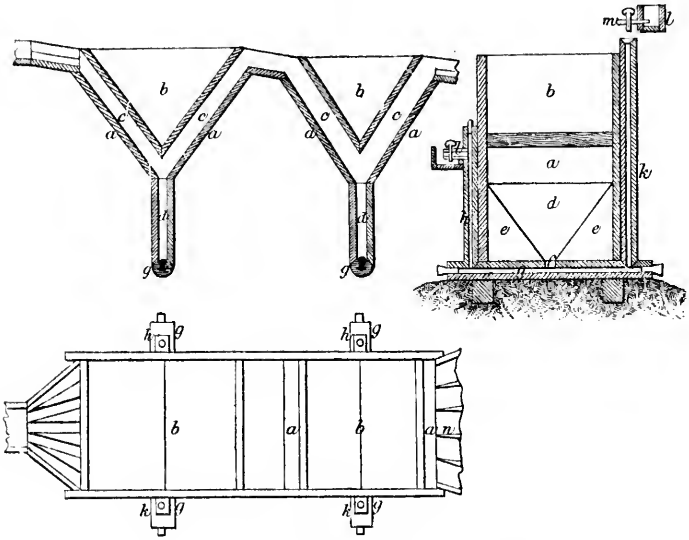
The third box separates 18 to 20 per cent., containing per cub. ft., 15 to 16 lb. coarse slime.

The largest box separates 10 to 12 per cent., containing per cub. ft., 10 to 12 lb. fine slime.

These are results in every respect satisfactory for the further concentration of the ore. As regards the loss caused through the final escape of impalpable ore from the last box, it amounts for rich galena-ores to about 6 per cent., and for quartziferous silver-ores to about $2\frac{1}{2}$ per cent.

Triangular Double Troughs.—Classification in the triangular double troughs or *Spitzlutten*, an invention by Rittinger, is based upon the principle that, if material composed of particles differing in size and density is exposed to a rising stream of water, the velocity of this stream may be so regulated that particles of certain size and character sink and may be conveyed off, whilst the remainder is carried upward by it; and that, consequently, by repeating this operation a certain number of times with a gradually decreased velocity of the rising stream each time, the material can thereby be separated in as many different classes of grains. The *Spitzlutten* (Fig. 165), by which this action is now very simply produced, are constructed as follows:—Within a triangular trough *a* of certain length and width, with two opposite sides vertical and two inclined at angles of 60°, is a similar smaller one *b*, having the vertical sides in common with the larger trough, but its inclined sides fixed at certain equal distances from, and parallel to, those of the latter. There is thus an open V-like space *c* left between the inclined sides of the two troughs, representing, as it were, a rectangular pipe, sharply bent in the centre; and it is through this that the stream of material has to pass—i. e. to fall and rise. The velocity of the stream depends on the size of this space, and consequently so does the size of the particles that will rise or sink in it. The cross-section and respective velocity stand in inverse relation to each other, and their determination for each double trough of a com-

FIG. 165.



TRIANGULAR DOUBLE TROUGHS OR SPITZLUTTEN.

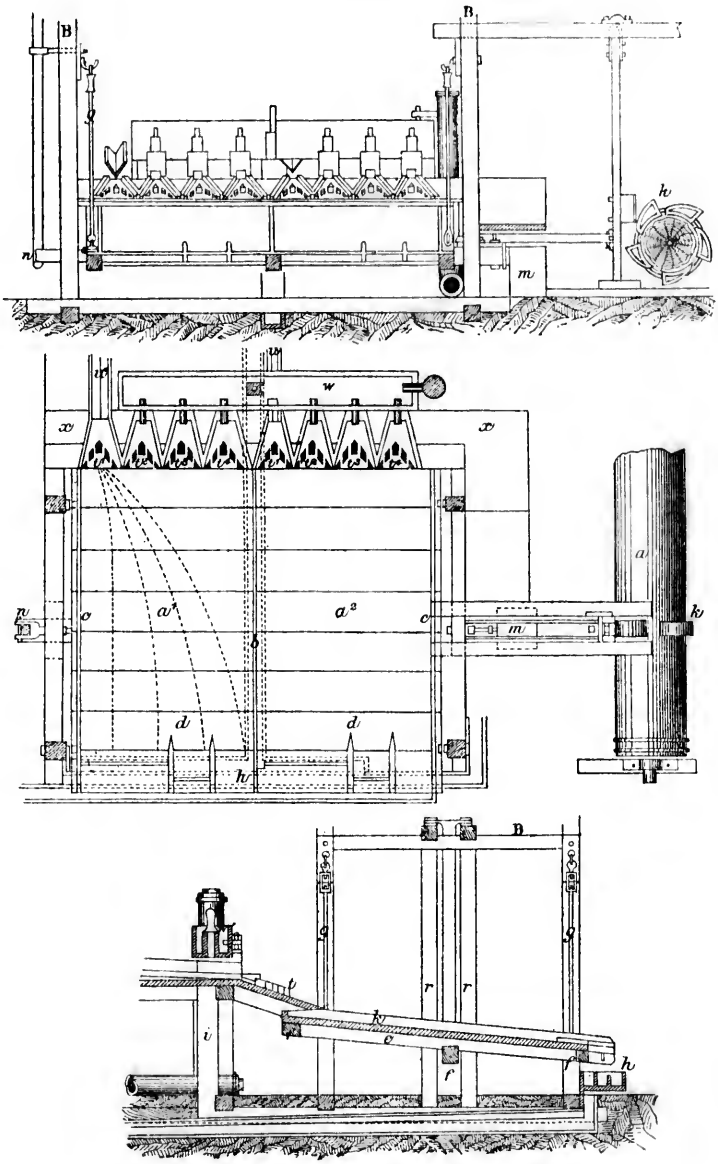
plete apparatus is a matter of mathematical calculation, in which the size of the largest particles and the specific weight of the material to be classified form the main figures. For galena-ores, such as those under notice, and which are crushed so fine that the largest grains are not more than 0·6 millimetre in diameter, the most satisfactory classification into 4 different kinds of grains is, according to Rittinger's calculation, arrived at by a series of four double troughs, with the velocity of the stream decreasing from the first to the succeeding troughs in the progression of 2·3, 0·94, 0·37, 0·15 in. per second; and if the width of the channel for the first trough is 1·1 in., and its length 2 ft., the dimensions of that of the second trough follow as 2·75 in. : 2 ft. And as it is not advisable to increase the width of the channels beyond 3 in., the channels of the third and fourth troughs are each 3 in. wide, and respectively about 54·5 in. and 135 in. long. The mean depth of the channels, measured from the line of inflow of the material to the lowest part of the inside trough, is for the two smaller double troughs about 3 ft.; for the two larger ones, 4 to 6 ft. In order to carry off the coarse particles that sink in the channels, the inclined sides of the outside troughs do not meet below, but are continued downward, forming a long and narrow pyramidal opening *d*, about 1½ in. wide at top. The short sides *e* slope inwards at an angle of not less than 50°, contracting the opening to a small hole *f* of about 1 in. sq. at bottom, through which the material is discharged into a horizontal pipe *g*, that extends both ways a small distance beyond the sides of the apparatus, and is connected at the ends with vertical 1-in. pipes. One of these *h* serves for the outlet of the classified material, and is carried up to within 36 to 21 in. of the water-level in the channel *c*, according to the degree of fineness of the particles that have to pass through it (the same as in the pyramidal boxes). At the top it is supplied with a tap for the regulation of the outflow. The other pipe *k* conveys a supply of clear water, furnished from a launder *l* supplied with a tap *m*, and as the water in the pipe stands 6 to 8 in. above the water-level in the trough, a small uniform pressure is produced, causing a forced influx of water at the point *f*, which is essential for good classification. This water—opposing itself to the downward current, charged with sediment in the pyramidal channel *d*—prevents all but the coarser particles and pure water passing into the pipe *h*, and thus only grains of the desired size are carried to the outlet *i*. With regard to the relative positions of the different double troughs of the series, they are fixed exactly horizontal, and sufficiently below each other to prevent any settlement of material in the communication-launders *n*, which are necessarily very broad. Other particulars regarding proper working, supervision, &c., are the same as those given for the pyramidal boxes. According to present experience, a series of 4 of these double troughs classifies as well as, and, for the two coarser kinds of grains, even better and cleaner than, a set of 4 pyramidal boxes, though for the fine slimes these latter are generally preferred, as they effect the desired settlement of the stuff more completely. A complete apparatus of troughs requires also less fall and space than one of pyramidal boxes, and is more easily regulated in cases of increased or diminished influx of material. The necessary additional supply of clear water might, however, form a drawback to its application in cases where this medium is scarce. As regards the results of classification by the different troughs of the series, they are stated to be as follows:—The first or smallest trough separates about 30 per cent. of coarse sand; the second, about 25 per cent. of fine sand; the third, 20 per cent. of coarse slime; the fourth, 15 per cent. of fine slime.

Concentration.—Having classified the material according to size, the next step is to submit each separate size to a process of concentration, with the object of eliminating the valuable portion. For this purpose many apparatus are in use, all working upon the principle of taking advantage of the greater specific gravity of the part sought to be saved.

Percussion-tables.—The most highly perfected of the various percussion-tables or shaking-tables is Rittinger's continuously-acting side-throw percussion-table, shown in Fig. 166.

To simplify the construction and movement of these tables, they are generally made so that they represent one large table, divided by a cheek *b* in the centre into two (a^1 and a^2), for the movement of which consequently only one arrangement is required, rendering the percussion simultaneous for both. The floor or platform of each table (a^1 and a^2), measured inside the head-board and cheeks *c*, which are about 4 in. high and 1½ in. thick, is 8 ft. long and 50 in. wide. It is generally double boarded, the upper surface being made of tongued-and-grooved 1¼-in. boards of some even, close-grained wood (generally sycamore), planed as exactly as possible, and slightly blackened by weak sulphuric acid. The boards are carefully laid crossways, and fixed with wooden pegs to the lower floor, made of pine-boards tightly screwed to a stout wooden frame, consisting of 4 or 5 bars *e* lengthways, and 3 *f* across, which are mortised and screwed together and secured by iron angle-braces. The centre crossbar *f* is nearly double as strong as the others, and projects on both sides a certain distance beyond the platform. It is called the "tongue" or "percussion-bar," as it forms the part to which the side-movement and percussion of the table is imparted. The double table is suspended by 4 iron rods *g*, having adjusting shackles, and at either end eyes that are connected with hooks, the upper ones screwed into stout uprights, that form part of a strong framing *b*, braced well together at top and bottom; the lower ones screwed into the sides of the platform frame at about 1 ft. from either end. The arrangement for imparting the side-way motion and percussion to the tables consists, in the first instance, of a wooden axle *a*, furnished with 4 or 5 cast-iron cams *k*, opposite the centre of the table. This axle is turned by an endless strap from a shaft connected with the axle of a water-wheel. The cams act upon—i.e. push forward—the iron-faced projection of a vertically-suspended wooden lever, which swings at its upper end on small iron pivots between two crossbars connected with the framing, whilst its lower end moves between guiding ledges, nailed to the floor of the building. About level with the frame of the table the ends of 2 wrought-iron

FIG. 166.



RITTINGER'S PERCUSSION-TABLE.

bridles are joined to it by means of a screw-bolt. These bridles transfer the forward movement of the lever to the table by being fixed with a screw-collar over a horizontal screw-spindle, that is fastened and adjusted on top of the projecting portion of the percussion-bar or tongue, and by means of which the length of the forward movement—i. e. the side-throw—can be regulated. The end of the projection of the percussion-bar, being slightly rounded off in front and strengthened by an iron rim, presses, when at rest, against the bumping-block *m*—a stout square pillar—which is joined to a foot-piece, 5 or 6 ft. deep in the ground, and well stayed at the back to resist the shocks, and its face, at the place of contact with the percussion-bar, is generally covered with leather for the purpose of deadening the blows. The pressure of the percussion-bar against the bumping-block is produced by a stout spring *n* of iron or some tough wood, attached to its prolonged end at the opposite side of the table, and can be regulated by a screw, that adjusts the tension of the spring. Both prolongations of the percussion-bar move on each side between two uprights *r*, connected with the outside framing, by which means the transversal movement of the double table is guided.

The following is a somewhat more simple arrangement for moving the table, and is similar to that used for the common percussion-table. The cams of the driver are made to act against the iron-faced top end of a lever, that moves on an axle at foot, and to which is attached, by means of a regulating screw, a horizontal wooden bar. This slides between guides, fixed on top of the bumping-block, and at the other end is in contact with an oblong block of hard wood, screwed on top of the prolongation of the percussion-bar. In order to prevent the horizontal bar and lever from jumping back too far when the table strikes against the bumping-block, the bar is furnished with a bolt, which ensures the normal position by resting against guiding-ledges on top of the bumping-block. The other arrangements, as regards the spring, regulation of pressure, &c., are the same.

The tables receive their supplies of classified material and of a necessary amount of cleaning water, evenly distributed by means of triangular inclined dividing-planes t^1, &c.,—furnished with wooden buttons in the usual manner,—from separate troughs *w*, into which the material and water are conveyed by small launders or pipes *u*, from the respective classifier and main water-launder. The whole of this arrangement, inclusive of platforms *x* for the workmen to stand on, rest on a low framing *i* above the head of the table. There are generally 3 or 4 dividing-planes t^1 to t^4 for each table, one of which supplies the classified material for a breadth of 8 to 10 in. at that side of each table opposite to where the percussion takes place, whilst 2 or 3 others provide the cleaning or washing water, the one nearest the percussion side always in somewhat larger quantity.

The principle upon which the ore-concentration on these tables is based, differs from that of the common percussion-tables mainly in the side action of the percussion on the stuff treated, which produces two movements of the particles, viz. one down the incline, the other forward; and in the mean direction resulting from this—i. e. diagonally downward, —they pass off the table. As now the heavier particles—i. e. the ore— are not only thrown farther, but are also, on account of their stronger friction on the boards, more or longer exposed to the forward movement than lighter ones (waste) during the same interval of time, it follows that they travel outside these, gradually separate according to their specific weights into distinct bands, and that this separation becomes more perfect, the nearer they approach the end of the table. The whole of this action is at the same time enhanced by the "cleaning-water." This prevents the stuff from spreading at once all over the table; it cleans the outside streaks of ore, and the stronger portion serves specially for washing the ore finally off the apparatus. For securing the partitions of the different portions of ore, separated on the table, small, pointed, movable pieces of wood *d*, called "tongues" or "pointers," are screwed upon the table near its foot, by means of which the streaks of ore are divided from that of the waste, and guided through narrow slits in the table, furnished with sheet-iron lips, into separate launders *h*, underneath, that discharge into settling- or catch-pits; or else the ore passes off the table over small movable strakes into launders placed in front. The waste runs off the table in both cases over a broad strake into a small launder in front, that conveys it to the main waste channel. In this, and in all instances where the discharge takes place over the front of the table, it is, like the slits above mentioned, provided with sheet-iron lips, projecting about 2 in., in order to prevent the stuff licking back underneath.

The result produced by the operation of these tables on any of the four previously classified portions of the stuff under notice is, to divide them into five products, viz.:—

1. Lead-ore, containing fine free gold.
2. Lead-ore, poor in gold.
3. Copper- and iron-pyrites, mixed with some lead-ore.
4. Poor ore-slime (i. e. imperfectly concentrated); and,
5. Waste.

These run in as many well-defined streaks down the tables, and are, as above described, parted by the pointers *d* and guided, the first three, into launders communicating with separate settling-pits; the fourth, into a strake, that conveys it to a catch-pit, from whence a Jacob's ladder, or lifting-wheel, raises it into a small pyramidal box for re-classification—the portion issuing from the apex orifice being then conveyed to, and re-treated on, a separate table. The quality of the three first portions of ore collected in the settling-pits is such as to render them fit for direct metallurgical treatment, the auriferous portion being, however, previously submitted to gold extraction, as will be seen hereafter. There are many conditions, as regards adjustment of stroke, supply of material and washing-water, &c., necessary to ensure the satisfactory working of this machine. This is shown by the following table (prepared by Franz Rauen), which gives the results of practical experience in treating the four classified portions of sands and slimes, both of auriferous lead-ores and silver-ores.

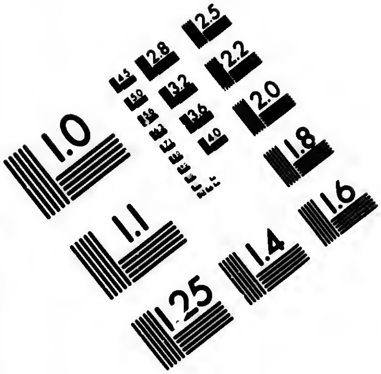
ADJUSTMENTS OF RITTINGER'S CONTINUOUSLY-ACTING SIDE-THROW PERCUSSION-TABLE.

Description of Ores.	Inclination of the Table.		Constant pressure of table against bumping-block.	Throw or Stroke.		Supply of material and cleaning water per minute upon a double table.				
						Classified Material.			Cleaning Water.	
	In the direction of the throw.	Towards the front.		Length.	Number of throws per minute.	Supply in cub. ft.	Weight.	Solid contents carried by the water.	Front cleaning water.	Back cleaning water.
FOR AURIFEROUS LEAD-ORES.	Lines.	Lines.	lb.	Lines	No.	Cub. ft.	lb.	lb.	Cub. ft.	Cub. ft.
Coarse Sand, 1st Classifier..	..	84	140	24	73	0·392	23·51	2·665	1·023	1·251
Fine do. 2nd do.	6	58	110	21	85	0·333	20·09	1·763	1·093	1·234
Coarse Slime, 3rd do.	7	56	106	18	100–105	0·323	18·94	0·914	0·888	0·977
Fine do. 4th do.	14	52	100	10	112–130	0·236	14·07	0·750	0·669	0·914
FOR SILVER-ORES:										
Coarse Sand, 1st Classifier..	6	72	212	18	76–78	0·420	26·64	4·956	0·711	1·187
Fine do. 2nd do.	6	54	183	12	86–88	0·405	24·80	3·410	0·256	0·677
Coarse and Fine Slimes } 3rd and 4th Classifiers	6	30	100	10	100–110	0·261	16·55	3·580	0·313	0·708

Another condition, not less important than those just given, for good concentration of the different classified portions of material, is the proper regulation of the velocity of the throw. For the tables applied to the treatment of the two coarser sizes, it ought, in the average, not to exceed 1 ft. per second, whilst slime-tables require a velocity of stroke of only 0·5 ft. per second; a greater velocity causes the tables to slide, so to speak, from underneath the particles of ore, thus retarding their progress.

The motive power required for working a double table is, by dynamometric experiments proved to be, 0·26 H.P.; and the working effect per hour of a single table is 55 lb. of slimes and 300 lb. of sands. Six continuously-acting double tables are capable of working in 24 hours 10 to 12½ tons of crushed material, classified by four pyramidal boxes. Four of these treat the four classified portions—i. e. each table is devoted to one particular class—and the two remaining ones are necessary for re-working the intermediate products—i. e. the imperfectly concentrated ore matter. As regards supervision and manual labour required, one workman is quite sufficient for attending on two properly-adjusted double tables. His principal work consists in looking after the right position of the "pointers," and the steady and regular supply of material and cleaning-water. On comparing the relative quantities of ore produced and the loss sustained during the same time by this and the old percussion-table, the produce of the former is 3 to 4 per cent. smaller than that of the latter, and its loss of ore about 2 per cent. larger—i. e. the new table loses 23 to 24 per cent., whilst the old one only loses 21 to 22 per cent. These disadvantages of the new invention are, however, more than compensated by the greater purity of its ore, effecting a saving both in transport and smelting expenses, and more especially by the greater amount of free gold contained in the auriferous portion. But it greatly excels the old table on account of its continuous, steady self-action; and consequently its working expenses are, without regard to wear and tear, fully 60 per cent. lower than those of the other.

Rotating table.—Rittinger's rotating table, Fig. 167, is specially applicable for the concentration of fine slimes, and for this operation is preferred to both the common and side-thrown percussion-tables. The concentrating portion—i. e. the table proper—may be described as a shallow, inverted-conical or flat funnel-shaped ring, consisting of even-grained, well-planed 1-in. pine-boards. The outer diameter is 16 to 18 ft., and the inner 5 to 6 ft., with an inclination of 6 in. to its radial width. It is furnished round the outer periphery with a rim of board 2 to 3 in. high, and is divided radially by narrow battens into 32 equal segments, that are somewhat contracted at the inner periphery by the ends of the battens being split, where, attached to the end of each segment, is a funnel-shaped descending pipe of wood or sheet-iron *v*, serving for discharge into receptacles beneath. This ring rests exactly horizontal, or rather the boards which it consists of are fastened horizontally crossways and watertight, upon 16 radial wooden bars or arms *r*, attached by means of a cast-iron rosette *q* to a central vertical wooden axle *s* of 16 in. diameter, to which (and consequently to the table) a slow, steady revolving motion is imparted by means of a tangent-screw, from a shaft, connected with the water-wheel. The tangent-screw operates upon a finely toothed cast-iron wheel, about 2½ to 3 ft. in diameter, fixed on top of the axle. The lower pivot of the latter turns in strong cast-iron bearings, whilst the upper one revolves within an iron collar; the bearing and collar, being fixed to a strong framing, consisting of 8 radial spars at top and bottom, connected, about 1 ft. outside the



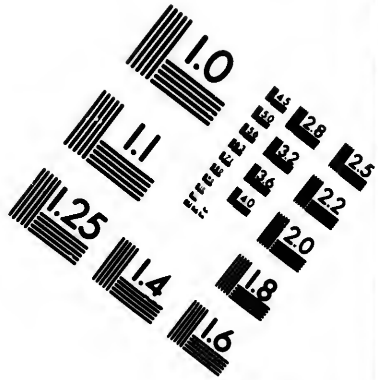
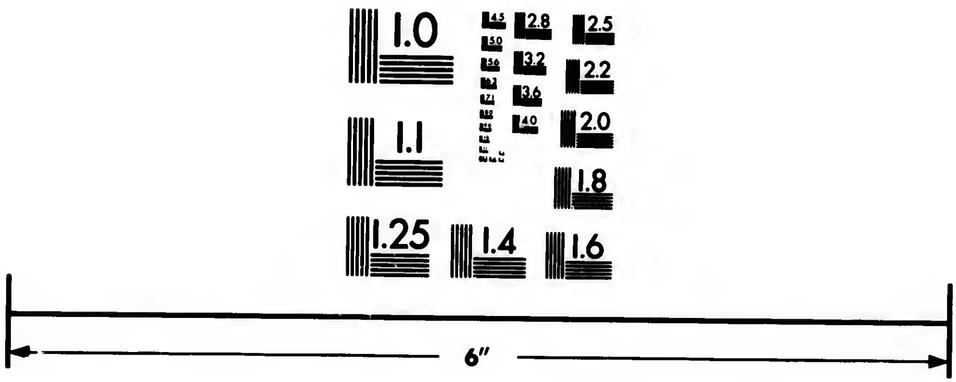
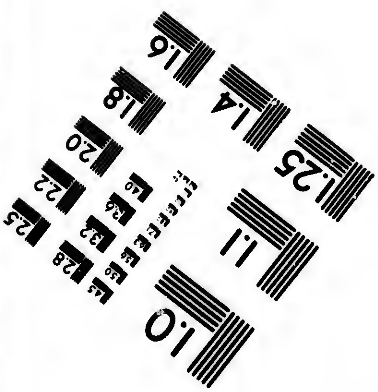


IMAGE EVALUATION TEST TARGET (MT-3)

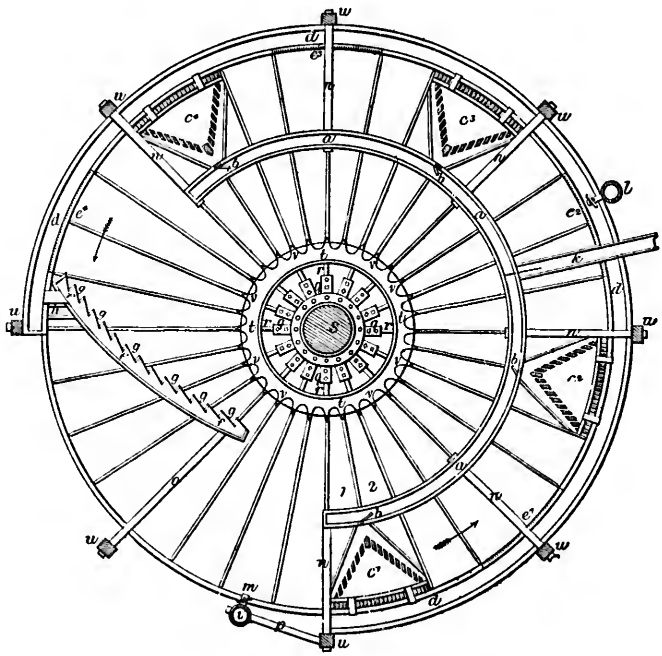




circumference of the table, by as many stout uprights *u*, and strengthened above and below by 4 braces, forming squares, near the centre. To this framing are attached all supplementary portions of the table, that take no part in its motion, such as the troughs for supply of clear water and material, triangular distributing-planes, &c.

The circular trough *a* that supplies the material consists of boards or sheet-iron, is 3 to 4 in. wide, and extends over 20 segments of the table. It rests horizontally on supports *n*, fastened to the uprights *u* of

FIG. 167.



RITTINGER'S ROTATING TABLE.

the framing, within about $2\frac{1}{2}$ ft. of the outer periphery of the table, and at such a height above it that the triangular distributing-tables *c*, that introduce the material close within its rim, have a fall of at least 20°. The bottom of the circular trough, from the point where a launder *k* introduces the material from the classifier—i. e. just at the centre of the curve,—is saddle-backed at a fall of about $\frac{1}{2}$ in. per ft., which prevents the stuff from settling. Up the centre of the mouth of the launder *k* a small movable tongue of wood is fixed to distribute the material equally towards both sides of the saddle. There are generally 4—sometimes 5—square openings *b* through the outer rim at the bottom of the trough, also provided with tongues, to regulate the outflow of the material on to as many triangular distributing-tables $c^{1,2,3,4}$, the relative positions of the openings being such that one is near each end of the trough, and the other 2 or 3, as the case may be, are placed respectively at equal distances from these and between each other. As regards the triangular distributing-planes *c*, they are fastened with their pointed ends by means of bolts and eyes underneath the trough, whilst their lower edges have hook-like strips of sheet-iron attached, by means of which they hang firmly on the inner rim of the main clear-water trough *d*, presently to be described. This arrangement, though ensuring a fixed position of the planes, yet permits their easy removal in cases of access to the table being required. They are, as usual, constructed of pine-boards, to which oblong, wooden, distributing-buttons are fixed; but they have, for the more equal distribution of the material, attached to their lower edges either pieces of sheet-iron with serrated lips, or are provided harrow-like with a number of thin iron spikes. The width of these lower edges, which are concentric with the table, is $\frac{1}{16}$ of the circumference of the latter—i. e. each supplies 2 of the 32 segments at a time.

The main clear-water trough *d*, constructed of boards or sheet-iron, is likewise circularly bent, and rests horizontally 3 or 4 in. above the circumference of the table on flat iron supports, projecting from the uprights *u* of the framing. Its inner rim lies just within the rim of the table; the outer one touches the uprights, and is attached to them. It commences radially abreast of one of the ends of the feeding-trough *a*, just level with the first distributing-plane c^1, but it extends 4 segments beyond the last distributing-plane c^4 at the opposite end of the trough *a*, and encompasses in all 24 segments of the table. It is constantly and in regulatable quantity kept supplied with clear water by means of a tap *b*. The amount required for concentration runs from the trough on to the circumference of the table through open cuts e^1, e^2, e^3, e^4 in its inner rim, 2½ in. deep, and as wide as suffices for the supply of 2 segments of the table. For the equal distribution of the water, sheet-iron plates, deeply serrated on both edges, are fixed in front of these cuts (indicated by dark lines on the sketch). The teeth of the lower edges of the plates stand about 1½ to 2 in. off the surface of the table, whilst those of the upper edges reach to within 1½ in. of the level of the outer rim of the trough. The number of the places of overflow $e^{1,2,3,4}$ corresponds with that of the distributing-tables *c* furnishing the material, and they are so arranged that if, for instance, there are 4 such tables, 3 overflows e^1, e^2, e^3 occupy the centres of the spaces—i. e. they supply the 2 middle segments of the 4 between these tables, whilst the fourth e^4 lies

2 segments beyond the fourth table. Adjoining this last place of outflow, and communicating by a short spout *h* with the main trough *d*, a peculiarly-constructed special clear-water trough *f* commences and extends horizontally in a flat curve across 6 segments of the table to near the inner periphery of the latter, where its end rests on a strong support *o*, projecting from the nearest upright *u* of the framing. The outer rim of this trough is even, but the inner one presents a succession of deep notches or breaks, and the dark lines *g* signify the places lower than the rest, where the clear water flows over the serrated sheet-iron plates, that extend down to within 2 in. of the surface of the table. And as they thus have to follow the inclination of the table, whilst the trough lies level, they become gradually longer towards the end of the trough. The special purpose which this trough serves for the material under notice is the separation of the pyrites from the lead-ore. As regards the arrangement for washing this ore off the table, it consists of a vertical pipe *i*, that by means of a flat mouthpiece *m*, 10 lines wide and 3 lines high, discharges, under a pressure of 8 to 9 ft. and at a very oblique angle, a stream of clear water on to the table near its rim. This pipe is closed at the bottom, and communicates at the top with a reservoir or launder. It rests on a support *p* projecting from the nearest frame-upright *u*, close outside the circumference of the table, and in the centre of the space between the commencement of the main clear-water trough *d* and the end of the special one *f* just described, a spot coinciding with the centre of the middle one of the 3 remaining segments of the table.

For the separate reception of the three kinds of material—viz. waste, pyrites, and lead-ore,—that run off the table at its inner periphery (through the funnel-shaped pipes *v* attached to the contracted ends of the segments), either one circular trough *t* divided by 2 partitions into 3 compartments, or else 2 separate troughs, one within the other, are used, the outer one of which is devoted to the waste, whilst the inner one receives the 2 kinds of ore into separate compartments by means of 2 short, shallow strakes, resting on top of the outer trough. The positions and lengths of the respective compartments correspond, of course, with the number and positions of the segments of the table, from which, waste, pyrites, and lead-ore are washed off. The troughs rest on the foundation-bars of the framing, and the compartments for the 3 products communicate by holes in their bottoms with separate launders underneath, that conduct the ore to settling-pits outside the table, and the waste into the main waste-channel.

The mode of action of this table is very simple, and its working requires no manual labour whatever; the machine is, in fact, like the percussion-table—self-acting. The process of concentration on the two segments 1 2 is, for instance, as follows:—Being coated with material by the triangular plane c^1, they pass during the slow rotation of the table underneath the first overflow *e* from the main clear-water trough *d*, and the ore deposited on them is cleaned from the waste; but, progressing farther, they receive a fresh supply of material from the second distributing-table c^2, are again cleaned by the second overflow e^2 of clear water, and after having undergone this double operation twice more, they progress underneath the special cleaning-trough *f*. On account of the inwardly-bent form of this trough, the numerous streams of clear water, issuing from it at *g*, act gradually on nearly the whole surface of the segments, completely washing off the pyrites and leaving them coated with pure lead-ore only, which, on farther progression, is also removed by the forcible stream of water, discharged from the mouthpiece *m* of the vertical pipe *i*. With this operation a full rotation of the table is completed, and the whole process, as regards the 2 segments, commences again. But it will no doubt be understood, that every 2 segments composing the table undergo the same operation in steady regular succession, and that the concentration is thus continuous, as long as the table rotates.

The conditions necessary for satisfactory working of the machine are the following:—

1. The supply of material for 4 to 5 simultaneous coatings ought not to exceed 0·6 to 0·7 cub. ft. per minute.

2. The solid contents per cub. ft. of supply must not amount to more than 1 to 1·25 lb.

3. 2·25 to 2·40 cub. ft. of clear water are required per minute, i. e. 0·75 to 0·80 cub. ft. for separating the lead-ore from waste and pyrites, and 1·5 to 1·6 cub. ft. per minute for washing it off the table.

4. The table must not rotate faster or slower than once every 10 minutes, i. e. 6 times per hour.

Comparative experiments touching the relative merits of this machine and the old percussion-table for the treatment of slimes, have proved that, whilst on the latter an amount of material holding 45 to 50 lb. of solid contents can per hour be passed through all stages of concentration to that of pure ore; the rotating-table accomplishes the same result in like time from a supply of similar stuff containing 90 to 120 lb. of solid matter—i. e. it concentrates fully double the quantity in the same time. The concentrated ore from both machines is equal, as regards purity, &c.; but comparing the relative amounts produced, viz. 80 per cent. by the new and 72 per cent. by the old one from an equal quantity of material, it follows that the old table loses 8 per cent. more than the new one.

As regards working expenses, the latter has also an important advantage over the former; for its supervision can be accomplished by a boy, whilst the manipulation on the percussion-table requires a strong and experienced person, whose wages are of course considerably higher, or nearly in the proportion of six to one. The expenses for working an amount of material with 5 tons of solid contents are, for instance, on the old table about 12*s*., on the new one a trifle over 2*s*. The motive power required for one of these tables is very small indeed, considering the size of the machine: 1 H.P. is quite sufficient to turn 10 to 15 of them.

There is a further special advantage connected with the construction and mode of action of this rotating table, namely, that with some modification in the arrangement of the supply and clean-water troughs, &c., and some additions, two different classes of material can, if required, be worked separately on one and the same table. For this purpose, 2 of the 4 triangular distributing-planes have to be devoted to each class of stuff. The supply- and reception-troughs have to be properly partitioned off, and there are in addition required one special cleaning-trough and one pipe for washing off the ore (both intermediate between the two pair of triangular planes), also double the number of launders for supplying stuff and conveying the products to their respective settling-pits.

Buddles.—Buddles are made in considerable variety, but mostly for dressing the ores of the base metals. The only one demanding notice for concentrating auriferous pyrites is that known as Munday's improved round buddle, shown in Fig. 168.

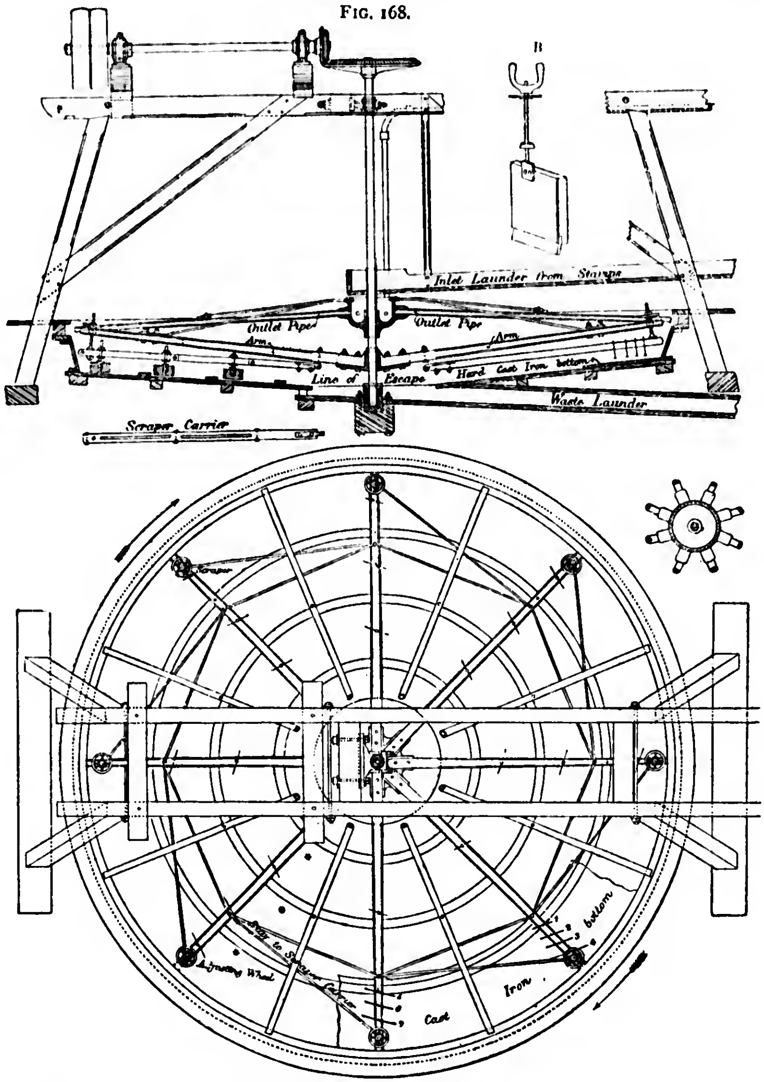
In this buddle, the sand enters the receiving trough fixed on the axle, and is thence conveyed through pipes to the rim of the basin, where it is discharged; the heavier portion of the sand thus treated gradually settles down to the bottom of the basin, while the lighter portion washes away. The detention of the heavy sand is facilitated by the scrapers being fixed angularly on the arms and intercepting the sand as it flows down from the edge toward the centre, and causing it to return toward the rim. The detention of the heavy sand is likewise facilitated by the recesses formed by the circular ribs attached to the bottom of the basin.

The action of the scrapers is believed to be improved by arranging them in a spiral form, one succeeding the other at about distances of 1½ in.

The heaviest portion of the material treated is found to accumulate within 2 ft. of the rim of the basin.

The circular basin may be made of wood, iron, or masonry, and of any convenient size from 12 up to 24 ft. diameter. Motive power may be communicated by belting or other means from existing machinery. The power to drive a 24-ft. buddle may be estimated at from 2 to 4 H.P.; the speed of the buddle is 5 revolutions a minute. Water from the stamps to be regulated according to the nature of the sand. A

FIG. 168.



MUNDAY'S ROUND BUDDLE.

buddle of 24 ft. diameter will efficiently treat from 20 to 30 tons of sand a day, taking it from the batteries. A slope of 1 in. to 1 ft. is generally given to the bottom of the basin. The angle at which the scrapers are set with the arms is about 18° from the right angle.

This buddle has been successfully adopted at the Port Phillip Company's works and the New North Clunes claim, at Clunes; at Llanberris, Ballarat; Koch's crushing plant, Sandhurst; the Walhalla claim at Stringer's Creek, and at several other mining claims in Victoria. But in some cases slight modifications are adopted. For instance, those used at the Port Phillip works are constructed of brickwork and cement instead of iron, and are then found to be cheaper while equally efficient. The ribs marked * in the plan are not used by Rosales at the Walhalla works; and the figures 1 to 7 show the position and angle at which the scrapers are set, Nos. 4 and 7 being 17 in. long, i.e. 1½ in. longer in front and 2 in. longer at the back than the others: Rosales prefers this arrangement to Munday's. The scrapers used by Rosales are of india-rubber, and their shape is shown at B, Fig. 168.

Bradford's Jig.—H. Bradford, of 2004 North Twenty-second St., Philadelphia, furnishes the following statement of results of a competitive trial in Colorado, on several thousand tons of gold- and silver-ores, between the German system of concentrating ores and his system. The ores were divided as they left the screens, one-half of the ore going to the German (Hartz) jig and the other half to the Bradford jig. The result was as follows:—

The crude ore averaged per ton	44.00
Tailings from Hartz jigs contained	13.96
,, Bradford ,, ...	4.11
Saving of Bradford over Hartz jig per ton	9.85

	per cent.
Percentage of assay value of crude ore saved by Bradford jigs	90·66
,, ,, ,, Hartz ,,	68·30
Difference in favour of Bradford jigs	22·36

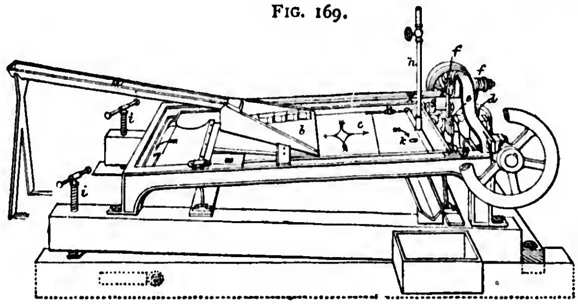
	$
Which, at $9.85 per ton saving over Hartz jig, would,	
on a 30-ton mill, amount per day to	295.50
,, 30 ,, ,, month to	7,683.00
,, 30 ,, ,, year to	92,196.00
Which would be 6 per cent. interest on a capital of	1,536,600.00

Imlays state that the Bradford jig does good work on coarsely-pulverized ores; but they have re-pulverized the tailings from his jig, and obtained another and a larger percentage of mineral.

Denny's Concentrator.—Denny makes a "percussion separator and concentrator" for treating auriferous wash-dirt and quartz tailings. It is said to treat 10 cub. yd. of tailings per hour most effectually.

Dodge's Concentrator.—The concentrator introduced by M. B. Dodge, and made by Malter, Lind, & Co., 189 Broadway, New York, is shown in Fig. 169. The pulp from the batteries flows down the sluice *a* on to the distributing-board *b*, which is provided with spreaders. The sluice and distributing-board are inclined in an opposite direction from the concentrating table *c*. The pulp is deposited evenly across the table by the spreader at a point just below the double arrow. Under the spreading-board is a riffle, to arrest the downward movement of the mineral when it leaves the spreader. An end shake is given by the cam *d* against the lug or tappet *e*, moving the concentrating-table gently forward, when the springs *f* draw the table suddenly back, striking on the upper corners of the table against the buffers *g*, which causes the pulp to move upwards on the machine. The pipe *h* delivers clear water,

FIG. 169.



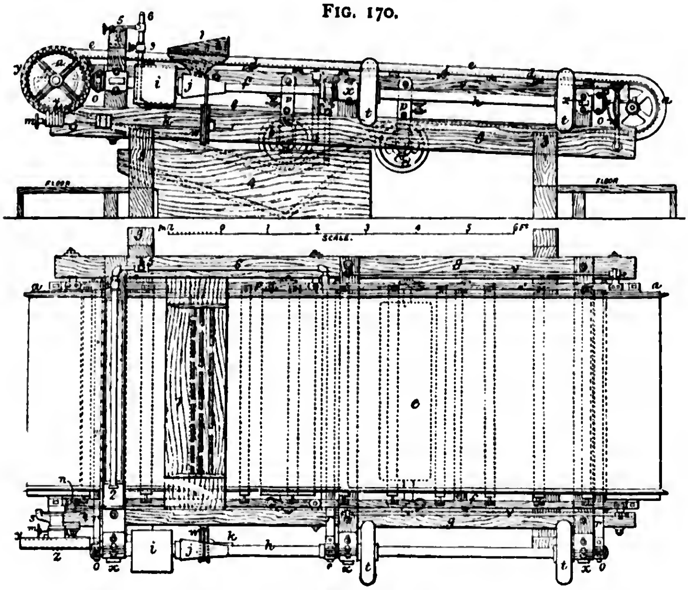
DODGE'S CONCENTRATOR.

through cross pipes provided with small orifices, in jets against the head of the table; the water flows downward in a thin sheet against the pulp, causing the gangue to move down and out of the table at the lower end, as shown by the arrow; while the mineral being heavier than the gangue, moves upwards, as shown by the double arrow, against the clear water into the depression and through the orifice. This orifice is provided with a wooden plug, with a suitable passage for mineral, and water enough to convey the concentrations down the short sluice into the box provided to receive them; thus forming a continuous discharge of mineral and gangue from the machine. At the lower end of the table is a receptacle to receive any fine mineral and mercury that might be left in the gangue while passing over it, which can be removed from time to time, or discharged continuously. This is one of the great advantages claimed for this concentrator over all others. The machine can be regulated for different kinds or grades of ores, by the amount of clear water turned on, and by the length of stroke, which is regulated by jam-nuts on the buffers *g*; also, by means of the screws *i* the machine may be raised or lowered to regulate the incline of the table. A great deal depends on the pressure put on the springs *f*.

Frue Vanner.—The Frue "vanner," made by Fraser and Chalmers, 145 Fulton St., Chicago, Ill., and by the Golden State and Miners' Iron

Works, is shown in Fig. 170. *a* are the main rollers that carry the belt and form the ends of the table ; each roller is 50 in. long and 13 in. in diameter. In order that they may be light, yet strong and durable, these rollers are made of No. 16 sheet-iron, riveted lengthways, and crowned in the centre about ⅛ in. The roller is secured at the ends by rivets to light cast-iron frames. The whole is galvanized when finished, so that even the rivets are protected from rust. The roller when finished is strong, and only weighs 70 lb. The bolts which fasten the boxes of *a* to the ends of *f*, also fasten to *f* the chilled cast-iron supports of the flat

FIG. 170.



FRUE VANNER.

bars of iron *n*. *b* and *c* are of the same diameter, and are made in the same way as *a*. The belt *e* passes through water underneath *b*, depositing its concentrations in the box 4 ; then, passing out of the water, the belt *e* passes over the tightening-roller *c*. *b* and *c* are hung to the shaking-frame *f* by straps *p*, which swing on the bolts fastening them to *f*. By means of the hand-wheels, *b* and *c* can be swung on either side, thus tightening and also controlling the belt.

The boxes holding *a* in place have slots, so that by drawing out or shortening, *a* can be made to create a very strong influence on the belt *e*; and as *e* sometimes travels too much toward one side, this tendency can be stopped most quickly by lengthening or shortening on one end or the other of *a*. The swinging of *b* and *c* out of line also controls the belt, but neither has influence equal to *a*. The small wooden rollers *d* and their support causes the belt *e* to form the surface of the evenly inclined plane table. This movable and shaking table has a frame *f* of ash, bolted together, and with *a* and *a* as its extremities. This frame is braced by 5 cross-pieces (shown by dotted lines). The bolts holding together the frames pass through the sides close to the cross-pieces; the cross-pieces are parallel with *a* and *d*, and their position can be understood by the 3 flat spring connections *r o*, which are bolted to 3 of them, one to each, underneath the frame. The belt *e* is 4 ft. wide, $27\frac{1}{2}$ ft. in entire length—being an endless belt of rubber with raised sides.

The stationary frame *g* is bound together by 3 cross-timbers, which are extended on one side to support the crank-shaft *h*. *g* supports the whole machine, and the grade or inclination of the belt is given by elevating or depressing the lower end of *g*. This is accomplished by means of wedges; for this frame rests on uprights 3, fastened to two sills, which form the foundation of the machines in the mill. *f* is supported on *g* by uprights *n*, 3 on each side. These uprights are of flat wrought iron, drawn to a knife-edge at each end, and case-hardened, with bearings above and below of chilled cast iron; each middle bearing on *f* has one bolt-hole, and there are two of them, one on each side. The end ones have two bolt-holes, and there are four of them, two on each side. These bolts pass through the frame *f*, and hold to the frame the bearings of *a*, which work in a slot. The bearings of the head-roller are higher than those of the foot-roller; i. e. *a* is a trifle higher than the regular plane of the table, and the first small roller *d* should be raised a trifle.

The cross-timbers binding together *g* and resting on them are extended on one side, and on these extensions rest with its connections the main or crank-shaft *h*, in bearings *x*; the cranks are $\frac{1}{2}$ in. out of centre, thus giving 1 in. throw. The driving-pulley *i* forms with its belt the entire connection with the power. *j* is a cone-pulley on the crank-shaft *h*. By shifting the small leather belt, the uphill travel of the main belt *e* is increased or diminished at will. The small belt connects to *j* the grooved pulley *w*, which is on the small shaft *k*, and by means of the hand wheel can be shifted on *k* and held in place. The two bearings of *k* are fastened to the swing-box *y*, a cast-iron shell protecting the worm *z* and worm-gear *l*; *y* turns on a bearing bolted to the outside of *g*, and thus becomes a swing-box for swinging *w* and *k*. The object gained by this is that the weight of *w* and *k* (swinging with *y*) hangs on the small leather belt, and keeps it tight, so that this small belt will last for a year without slipping or breaking. Before this improvement, the small belt was constantly breaking or slipping. In some cases, this movement is accomplished with step pulleys and flat belt. A hand-wheel *m* is used to relieve the small belt from part of the weight of *k* and *w*; by screwing it up, *k* and *w* can also be raised, taking all the strain off the small belt, and thus stopping the uphill travel. *k* terminates in a worm *z*, which connects with a worm-gear *l*, travelling in a bearing bolted to the outside of *g*. *z* and *l* are protected from dirt and water by the cast-iron shell *y* enveloping both.

The short shaft which *l* revolves terminates in an arm *s*, which drives a flat steel spring *q* (which is a section of a circle), connected with the gudgeon of *a*. *r* are 3 flat steel sp.ing connections bolted underneath the cross-pieces of *f*, and attached to the cranks of the shaft *h* by brass-boxes *o*. These springs give the quick lateral motion—about 200 a minute. *t* are two fly-wheels. *v* are two rods passing from the middle cross-timber to the upper bearings of the lower uprights *n*. The cast-iron washers on the bolts of the cross-timber have lugs cast on them, and so have the bearings of the lower *n*. *v* pass through these lugs, and at each end are nuts on each side of the lugs. Thus *v* prevent the whole movable frame *f* from sliding either up or down, and by them *f* is squared. 2 is the clear-water distributor, and is a wooden trough, which is supplied with water by a perforated pipe; the water discharges on the belt in drops by grooves 1$\frac{3}{4}$ in. apart. 1 is the ore-spreader, which moves with *f*, and delivers the ore and water evenly on the belt. 3 are upright posts, which are firmly fastened to two sills, forming the foundation for any number of machines. 4 is the concentration-box, in which the water is kept at the right height to wash the surface of the belt as it passes through. 5 are the cocks to regulate the water from the pipes 6.

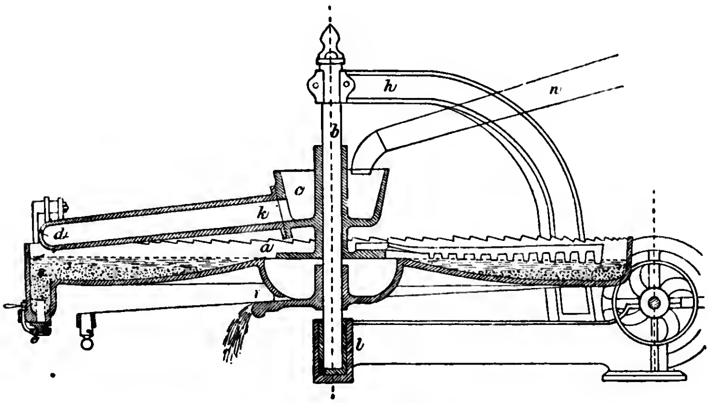
The ore is fed with water on the belt *e* by means of the spreader 1. Thus the feed is uniform across the belt. A small amount of clear water is distributed by 2. A depth of $\frac{1}{2}$ in. of sand and water is constantly kept on the table, and the table should receive about 200 shakes a minute. The uphill travel or progressive motion varies from 3 ft. to 12 ft. a minute, according to the ore, and the grade or inclination of the table is from 4 to 12 in. in 12 ft., varying with the ore. As previously explained, the inclination can be changed at will by wedges at the foot of the machine, these wedges being under the lower end of *g*, and resting on uprights from the main timber of the mill. The amount of water used, the grade, and the uphill travel must be regulated for every ore individually; but once established, no further trouble will be experienced in the manipulation. In setting up the machine, everything must be in line, except the tightener-roller *c*. The tightener-roller not only tightens the belt, but regulates it and keeps it in place on the table. This wide belt travels uphill very slowly, so that it takes several minutes to recover its central position on the table, and at times one bearing may necessarily be several inches farther up than the bearing on the opposite side, thus twisting *c* out of line. In treating ore directly from the stamp, too much water may possibly be used by the stamps for proper treatment of the sand by the machine. In such a case, there should be a box between the stamps and the concentrator, from which the sand with the proper amount of water can be drawn from the bottom, and the superfluous water will pass away from the top of the box; but as mineral will also pass away with this water, there should be settling-tanks for this water, and the settlings can be worked from time to time as they accumulate.

The surface of the belt lasts for 3 months at least. As soon as the belt shows wear, it should be preserved; and the belt should never be allowed to wear to the canvas. The belt is preserved by a coat of rubber paint, prepared expressly for the purpose. Accidental breaks in the belt may be repaired by rubber cement. In renewing the surface of the belt, it must be dry. The paint should be thinned, if necessary, with benzine and naphtha, so that it readily flows from the painter's brush. The surface of the belt should be cleaned with naphtha. Then, a man standing at the lower end *a* paints liberally across the belt, and for 2 or 3 ft. up, as he can conveniently reach; then revolves the belt in its usual direction, i. e. upwards, for a short distance, and paints another short piece. This operation is continued until the whole surface has been painted. The rubber paint dries almost immediately, and in a very short time the belt is ready for work again. Every two months this should be repeated. The paint should be put on uniformly, but not so hastily but that the portions painted have time to become nearly dry before reaching the tightener *c*. In using the paint, it must be kept well stirred. The main body of the belt suffers hardly any wear, since it merely drags its own weight slowly around the freely revolving rollers; and the life of the belt is lengthened by this precaution, viz. to keep it clean from sand at every point except the working surface, thus sand cannot come between the belt and the various rollers.

The concentration-box 4, which is kept full of water, and through which *e* passes, may be of any size or depth desired; in front of it may be an apron to catch any chance droppings of concentration from the belt. Though not indispensable, it is best to have a few jets of water playing above and underneath on the belt as it emerges from the water in 4, so as to wash back any fine material adhering to the belt, and as such a method will cause an overflow in 4, the waste water, being full of finely divided mineral, should be settled carefully in a box outside. Every few hours the concentration may be scraped out with a hoe, into a small box that can be placed under the inclined end of 4, and if this box be on wheels it can be readily run on a track to the place where the concentrations are stored; such a method seems clumsy, but there is comparatively a small quantity to handle. Frequently the sand on the belt forms a corner on each side, and to break up these corners and keep a uniform consistency on the belt, a system of drops or small jets of water can be used on each side to advantage. Such will help to increase the capacity of the machine, and will enable it to do uniformly better work.

Hendy's Concentrator.—This apparatus, Fig. 171, consists of a shallow iron pan, 5 to 6 ft. in diameter, supported by a vertical shaft in the centre, and made to oscillate to and fro by means of cranks on a shaft at one side, and joined by connecting-rods to the periphery of the pan. The pan turns for a short distance at every revolution of the crank-shaft. A frame supports the central pin and crank-shaft, as well as arched arms

FIG. 171.



HENDY'S CONCENTRATOR.

h, which rise over the pan and sustain the upper end of the vertical shaft *b*. The bottom of the pan is raised in the centre around the shaft, nearly to the height of the rim, and thence descends towards the periphery in a parabolic curve, by which the movement of the particles from the centre towards the circumference is facilitated, and their passage in the other direction obstructed.

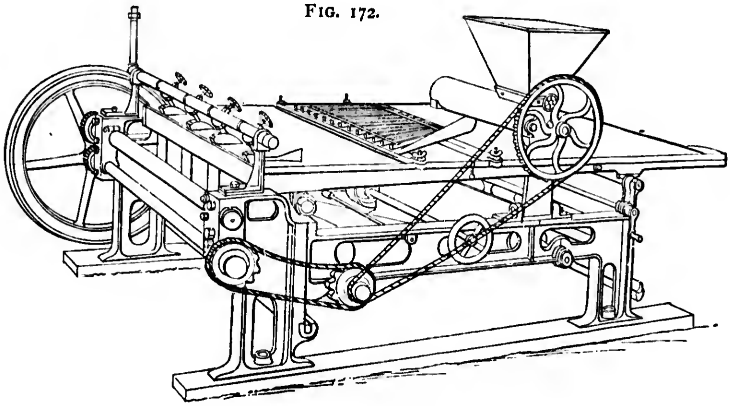
When placed for operation, the apparatus should be perfectly level. The stuff to be concentrated is delivered by the trough *n* to the hopper *c*, whence it is fed through the pipe *k* and distributor *d* into the pan near its outer edge. The feeding extends around the whole circumference by causing the distributor to rotate around the vertical shaft, accomplished by the movement of the pan. The upper edge of the pan is a continuous ratchet, into which 2 pawls connected with *d* drop during the motion of the pan from the distributor, and in the return motion give a velocity to the distributor equal to that of the pan. Continued impulses in this way keep the distributor in regular rotation around the shaft. Rake-like arms are bolted to a flange on the bottom of the hopper *c*, and are carried around with the distributor, serving to separate the compact mass of sand and pyrites as it settles, and breaking the scum that gathers on the surface. The crank-shaft makes 200 to 220 revolutions a minute, thus throwing the pan to and fro an equal number of times, and keeping the materials in a constant state of agitation. The heavier substances, such as the pyrites and any stray particles of mercury or amalgam, settle to the bottom, and accumulate in the lowest parts of the pan, gradually displacing the sand and lighter materials, which, with the excess of water, flow over the raised bottom at the centre, and out of the pan by a central discharge. The accumulated sulphurets are discharged at the gate *e*, the opening of which is regulated by a small handle at the front of the machine. The pyrites that are discharged may be received into boxes or troughs.

These machines weigh about 1000 lb. each. They are run by a belt, and usually set in pairs. The amount of water required is not large: not more than what flows away from the batteries with the sands to be concentrated. Each machine will receive and concentrate 5 tons of stuff every 24 hours; 8 tons have been put through in that time, but the product was not entirely free from sand, the presence of which is not objectionable in some processes of working, and if clean pyrites are desired, the discharge from 4 machines is delivered into a fifth, and this gives a complete clean concentration.

Imlay Concentrator.—Favourable accounts are given of the Imlay concentrator and amalgamator, shown in Fig. 172. Described generally, the machine consists of a flat table having a copper surface, with 2 upturned sides and one similar end, the opposite end being open to permit the discharge of the tailings. This table is set at an incline, varying from ½ to 2 in., the waste discharge end being lowest. At its opposite upper end, the table is provided with outlets for the reception and discharge of the concentrations. The table is supported upon 4 arms, one at or about each corner, which arms project upwardly from two transverse rock shafts at either end of the machine and about 1 ft. below the table; when motion is duly communicated, these arms vibrate to and fro, a longitudinal reciprocating movement, or a lengthwise movement of the tables being thus effected.

If this to and fro movement were in equal time, the results would not be those now obtained. Hence, a variable movement, which is the peculiar characteristic of this machine, is obtained by a very ingenious and yet simple combination of mechanism. The main shaft of the machine is provided with an eccentric gear-wheel, which meshes with a like gear on a counter-shaft, parallel with the main shaft. This counter-shaft is an eccentric or crank-shaft, from which two connecting-rods lead to the reciprocating-table. The eccentric gears communicate a variable rotary movement to the crank-shaft, and this, through the connecting-rods, produces the variable reciprocating lengthwise movement of the table. The effect of this movement is to cause any material above a

FIG. 172.



IMLAY CONCENTRATOR.

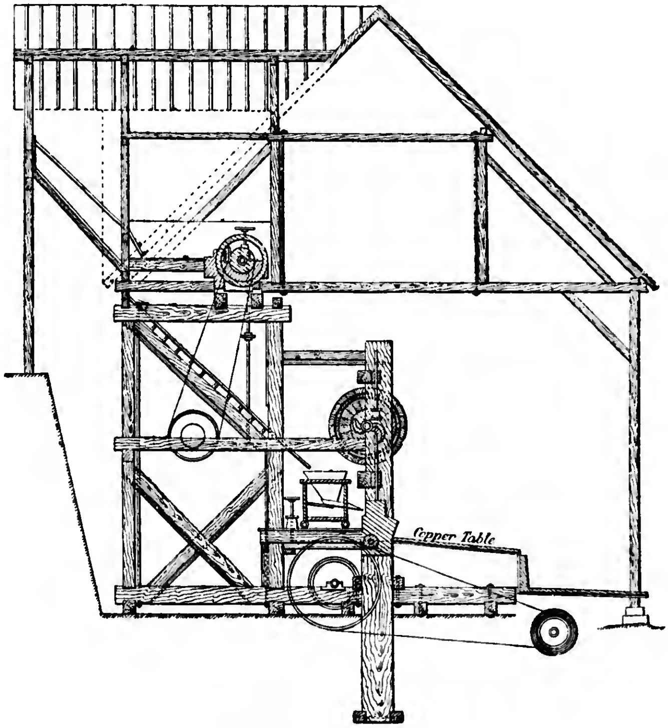
given specific gravity, laid upon or fed to the table, to travel upwardly upon the latter, while anything below such gravity will be caused to pass down the same. As the pulp almost invariably carries some mercury, the latter soon forms an amalgamated surface on the copper-plates.

COMPLETE MILLS.

Having described in detail the various operations incident to extracting gold from quartz, it will be interesting to conclude this chapter with some account of a few representative mills, both to convey a connected idea of the conduct and order of the processes employed, and for purposes of comparison of one with another.

Hite Mining Co.'s mill.—The Hite Mining Co.'s 40-stamp mill was constructed by Malter, Lind, and Co., of Broadway, New York, and California St., San Francisco, and contains all the recent improvements introduced by this firm in the large gold-quartz mills erected in the Black Hills, Dakota. The mill is established in Mariposa county, California, and is shown in Fig. 173. It is worked by water power derived from the south fork of the Mercer river. The ore from the mine is loaded on cars in the stopes and run out through the tunnel down an incline into the ore-house of the mill, where it is dumped (shot) over screens. The larger pieces of ore pass over the screen to the stone-breakers; the finer pieces go directly to the ore-bins and automatic feeders which supply the 40-stamp batteries. Each stamp weighs 750 lb.; 5 are placed in a set, and work in one mortar. They are raised by cams, and drop about 8 in. Amalgamation is partly effected in the mortars by means of electro-silvered amalgamated copper plates,

FIG. 173.



HITE MINING CO.'S MILL.

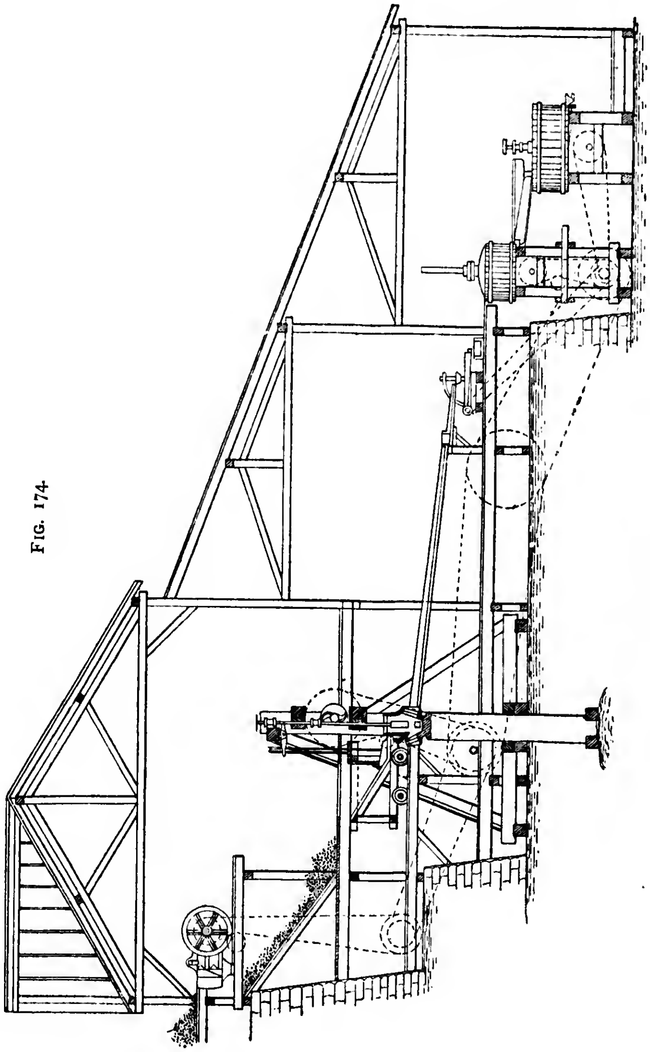
and partly outside the mortars on copper tables coated with mercury. The mill is estimated to work 100 tons of ore per diem, at a cost not exceeding $1 (4*s.* 2*d.*) per ton.

Placerville Co.'s mill.—The following information concerning the mill and processes of the Placerville Gold Quartz Mining Co., California, has been very obligingly communicated by the Chairman and Manager of the Company, in response to the author's request.

"The mill has 20 stamps, each stamp being of an average weight of 800 lb.; each battery of 5 stamps is furnished with a self-feeder. The self-feeders are connected with a large bin, having a capacity of 300 tons of quartz; the floor of this bin is placed at an angle of 50°, so that the quartz slides by gravity to the self-feeders. The quartz is delivered from the mine by a self-acting tramway to this bin, the fine material passing through a grating, the coarser lumps remaining on the floor of the rock-breaker, both the fine and crushed material falling by gravity into the fore-mentioned bin, so that the ore passes from the mouth of the shaft into the battery without the aid of any manual labour, with the exception of the labour in placing the large pieces of quartz into the rock-breaker. The mortar has but one discharge, and that in front; the screens are made of thin slotted Russian iron, equal to 450 holes to the sq. in.; inside of each battery in front is a slip of silvered copper-plate, 8 in. in width by the total length of the battery. Immediately in front of the battery again is a large silver-plated copper-plate, equal to the total width of the mortar, by 3 ft. in length, in front of which is placed again 20 ft. of 18-in. sluice, the bottom of which is lined with silver-plated copper-plates, constantly kept in a bright condition. The tailings are passed over Hendy's concentrators (there being one for each 5-stamp battery), again over 20 ft. of blanket sluices, and afterwards over 50 ft. of coarse canvas sluices, or rather sluices lined with such material, and finally over 64 ft. of riffle sluices. The material caught on the concentrators and blankets is passed through amalgamating-pan, settler, and agitator. The material saved on the coarse canvas and riffle sluices are further concentrated in a Cornish buddle, as are also all the tailings from the amalgamating-pan and settler. The quantity of mercury placed in the mortars or coffers is regulated by the appearance of the copper-plate in the front of the battery; the mercury is fed at intervals of half-an-hour. The blankets are washed every hour; the coarse canvas every 3 hours. The general arrangement of the mill is represented in Fig. 174. The tailings are regularly and carefully sampled; the same have been assayed with results varying from mere traces to 75 cents (3*s.* 1½*d.*) per ton; in one instance only did they ever reach as high as $1½ (6*s.* 3*d.*) per ton. We endeavour to arrange, as near as we possibly can, a speed of some 75 drops to the stamps per minute. Of course this could be largely increased, with consequent increase of crushing; but this would be at the expense of losing a much higher percentage of gold. We have never had any trouble with the flouring of the mercury.

"I will now make what comments I deem necessary on Mr. Lock's paper, read before the Society of Arts. I had read this paper before, as I am a subscriber to the Journal of this Society for many years. (1st.) In the matter of 'gauge of gratings or screens.' The size of the screens should depend entirely upon the fineness of the gold in the quartz. If the gold should be diffused in a finely divided state through the quartz,

FIG. 174.



PLACERVILLE GOLD QUARTZ MINING CO.'S MILL.

it is evident that finer crushing must be had than if the gold were coarse. I have given the size of the perforations of our screens. (2nd.) All the protection to the mortar by having the dies rest upon a layer of sand has always been in use. We have not had any broken mortar as yet. The stamp-heads and the dies upon which they strike are of the same size; this we consider a protection to the mortar and stamp-head, that is the layer of sand under the dies. With such fine gold as we have had to deal with at the Placerville, we could not expect much fine gold caught in this material. We rely upon our amalgamated copper plates inside of the battery for this purpose, and I have no hesitation in stating that this is by far the best way to catch the maximum amount of gold. In the early days of gold-mining in California, the stamps were used simply for the crushing of the ore, the amalgamation was conducted on the outside entirely; the only gold caught in the battery being coarse particles that could not pass through the screens. Experience has taught the mill-men here that this latter method is not only more expensive, but by far less effective. I cannot agree with Mr. Lock when he states, 'I venture to assert that this system of putting mercury into the stamp coffers and using amalgamating plates is radically wrong.' The difficulties that he speaks of, viz. the loss of mercury flouring, does not trouble us. I also claim that the particles of amalgam passing through the screens are caught either on the copper-plates in front, or on the Hendy concentrator, and if any escapes here, why we have the blankets, coarse canvas and riffle sluices, and finally the Cornish buddle.

"The last few weeks I have had some experience with the system designated as 'mercury riffles' and mercury troughs, as fully described in Mr. Lock's paper. I had to examine a mine where they were in use, having been put in and erected by an experienced Australian mill-man. I found the tailings containing an abnormal quantity of gold. The owners found it necessary to change this system to amalgamation on copper plates inside the battery, with the usual outside appendages, already described. (3.) The statement that the gold is flattened out by pulverization in the battery is not a fact, as the gold is really brittle, and is rather pulverized into small irregular particles than beaten or hammered out into thin plates. (4.) The flouring of the mercury is not caused by the presence of sulphide of iron, so far as my experience goes, but such is the case when sulphides of copper and lead are present in any considerable quantity. In all our clean-ups at the Placerville mill, we have never had any trouble with the 'flouring' or the 'sickening' of the mercury. The system of concentrating on blankets, as done in some places, collects not only the gold, but much of the metallic iron produced by the wear and tear of the shoes and dies. (5.) The only way to ascertain the true value of auriferous quartz, assaying only from $\frac{1}{4}$ to 1 oz. of gold per ton, when dealing with hundred of tons per month is, by a careful system of sampling the tailings. The total clean-up, plus amount in tailings, represent the total amount per ton. We sample our tailings at Placerville by taking a bucketful of tailings at regular intervals of 2 hours, water and all, from the final tailings through a large filter; at the end of each week the accumulated samples are averaged, and at the end of the month the weekly samples are again mixed, and an average sample taken, which I assay.

"Now, as to facts connected with the value of tailings from quartz mills in California. During the last 18 years I have been in this country I have had occasion to examine a very large number of gold quartz mines. At a very large number of these mines large piles of tailings had accumulated; many of these piles I have had occasion to sample, as they were represented to be very rich, but, as a rule, I did not find them sufficiently rich to pay for the handling. It is a very popular thing for a superintendent to say your mine is good, plenty of gold in the quartz, but it is so rebellious that it is impossible to save the gold. Many such a mine have I had occasion to examine, and, to the sorrow of the stockholders, found out that the rebellious character was due entirely to the fact that the quartz contained but little gold. I have no hesitation in stating that with proper care and attention the system I have described as in our mill at Placerville is more effective for the quartz we have to deal with than the one described by Mr. Lock. What gold we cannot save on the mortar-plates, copper plates in front, Hendy's concentrator, and the blankets and canvas, the riffle-boxes, and Cornish buddles will catch. I have endeavoured to cover the whole subject, and if I have not, please let me know, and I will give you any additional information I may have.

"(Signed) THOMAS PRICE."

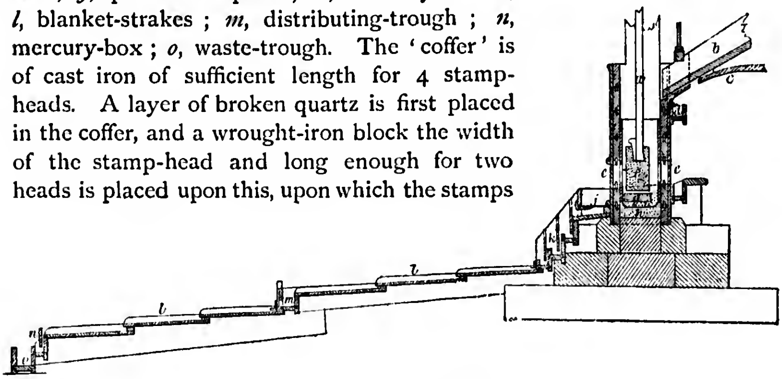
Port Phillip and Colonial Co.'s mill.—The Port Phillip and Colonial Gold Mining Co.'s works at Clunes, Victoria, Australia, are among the most perfect in the world, and their success is mainly due to the energy of the talented manager, R. H. Bland, who has very kindly furnished the following exhaustive account of the operations conducted under his direction.

"Operations at this mine were commenced early in 1857. The first battery of stamps was completed and got to work in May of that year, and comprised 20 heads of light stamps. These were rebuilt and added to from time to time as the supply of quartz increased. The present reduction plant comprises 80 heads of heavier stamps, 2 stone-breaking machines, and 7 buddles driven by one 24-in. cylinder engine, supplied with steam by 5 multitubular boilers with a pressure of 60 lb., working expansive, and condensing, with an indicated horse-power of 127.

"In addition to the above there are 5 cast-iron barrels for amalgamating the blanket sand, and 2 steam-barrels for saving ground-up mercury, driven by a separate 12-in. engine; also a set of double-acting 10-in. pumps capable of lifting 600 gal. of water per minute, driven by a 10-in. engine.

"Stamping Batteries.—These are built on the old principle, fitted with square-shaped stamps; 24 of these weigh with the lifters about 8 cwt. each, the remaining 56 weigh about 6½ cwt. each. The lifters are made of 2⅝ in. bar-iron, are driven at a speed of about 80 blows per minute, and crush an average of a little over 3 tons of quartz per head per diem of 24 hours. Fig. 175 shows the construction of the batteries: *a*, lifter; *b*, self-feeding hopper; *c*, spring; *d*, water-trough; *e*, escape; *f*, stamp-head; *g*, die; *h*, bottom box; *i*, loose bed; *j*, perforated plate; *k*, mercury-boxes; *l*, blanket-strakes; *m*, distributing-trough; *n*, mercury-box; *o*, waste-trough. The 'coffer' is of cast iron of sufficient length for 4 stamp-heads. A layer of broken quartz is first placed in the coffer, and a wrought-iron block the width of the stamp-head and long enough for two heads is placed upon this, upon which the stamps work. By this method, the cast-iron coffer remains uninjured, and it has the further advantage of allowing space for the coarser gold to accumulate directly it is liberated from the quartz without being further broken up by the stamps. The escape plates, placed back and front, are made of stout copper, perforated with a tapered punch, the smaller orifice being placed inside to facilitate the delivery of the crushed material. The water supplied to the stamps amounts to about 6 gal. per head per minute. The crushed material is conveyed to the mercury-boxes and over the blanket-strakes, and from thence to the buddles, where the pyrites is separated from the sand and kept for further treatment.

FIG. 175.



PORT PHILLIP BATTERY.

"Pyrites.—The quantity of pyrites contained in the quartz from this mine is estimated at about ¾ per cent., equal to 15 cwt. to the 100 tons. After being concentrated in the buddles, it is sent to the furnace, and roasted sufficiently to get rid of the sulphur and arsenic. It is then taken to the Chilian mills and ground with mercury. This operation is carried on as follows. Each mill-pan is charged with about 1 cwt. of roasted pyrites and about 80 lb. of mercury, and sufficient water to damp the material; it is then ground for about 20 minutes. Water is then turned on and grinding continued until the ground-up pyrites is washed away, leaving the amalgam in the pan; the process is then continued.

"The material washed from the pan is passed through a concentrator, and thence over a cradle covered with blanket to further arrest any particles of ground-up mercury and amalgam that may have escaped the mills. The material so saved is placed in one of the steam-barrels and kept revolving for two or three days. After making a good many trials, we found the method we now adopt to answer the best.

"The bye-products, such as sulphur and arsenic, are, however, all wasted; but this cannot be avoided.

"Returns.—The accompanying return (No. 1) shows the quantity of quartz raised each year from 1858, together with the gold obtained and the average yield. The total quartz raised and crushed for the 23 years was 1,140,653 tons, and gold yield 471,203 oz. 4 dwt. 13 gr.; value of the same, 1,885,805*l.* 3*s.* 2*d.*

"No. 2 is a return of pyrites saved and treated, together with the yield of gold, &c. The fluctuations in the yield are mainly due to the varying nature of the quartz, some of the lodes containing more pyrites than others.

"No. 3 is a return of the percentages of gold obtained from the various sources, such as stamp-beds, mercury-boxes, blankets, mills. At one time there was considerable difference of opinion as to comparative efficiency of the blankets and buddles, some contending that the former should be dispensed with. This was done for the greater part of two years, and then resumed, and the coupled return shows the advantage attending the use of both.

"Mine.—There are two engine-shafts at this mine. The north shaft is down 1193½ ft., and is supplied with a winding-engine of 24-in. cylinder and a very complete set of winding-gear, one 24-in. pumping-engine, and one capstan-engine, which also drives one of Root's blowers for driving air down the mine. These engines are supplied with steam from 4 tubular boilers. The south shaft is down 850 ft., and will be sunk at once to 900 ft. This shaft is supplied with a winding-engine and one boiler.

"The quartz from these two shafts is conveyed to the stamp-house by a very complete system of tramways.

"Four quartz lodes appeared on the surface at this mine, called respectively the 'Western,' 'Robinson's,' 'Old Man,' and the 'Eastern.' Subsequently another lode was discovered under the basalt and called the 'Welcome,' which, however, did not continue payable much below No. 5 level. Another vein called the 'New Eastern' was passed through

RETURN (No. 1) OF QUARTZ CRUSHED AND YIELD OF GOLD FROM 1857.

Year.	Company's Quartz. Tons.	Company's Quartz. Gold.	Company's Quartz. Average.	Company's Quartz. Value.	Tributors' Alluvial and Quartz. Tons.	Tributors' Alluvial and Quartz. Gold.	Tributors' Alluvial and Quartz. Value.	Totals. Gold.	Totals. Value.
		oz. dwt. gr.	oz. dwt. gr.	£ s. d.		oz. dwt. gr.	£ s. d.	oz. dwt. gr.	£ s. d.
1857 & 1858	15,466	22,545 3 18	1 9 0½	88,065 7 11	..	..	..	22,545 3 18	88,065 7 11
1859	17,542	18,165 12 12	1 0 17	71,490 4 8	..	(Alluvial) 9,375 4 0	36,897 6 2	27,540 16 12	108,387 10 10
1860	21,694	17,466 16 19	0 16 2½	68,476 5 8	..	..	..	17,466 16 19	68,476 5 8
1861	32,258	24,336 6 3	0 15 2½	95,708 13 3	..	..	..	24,336 6 3	95,708 13 3
1862	34,236	22,012 0 17	0 12 20	86,398 12 11	..	..	..	22,012 0 17	86,398 12 11
1863	40,360	22,988 1 19	0 11 0	91,336 5 8	..	..	..	22,988 1 19	91,336 5 8
1864	44,149	17,611 8 0	0 7 23½	69,694 7 2	..	..	..	17,611 8 0	69,694 7 2
1865	54,413	20,596 10 12	0 7 13¾	81,805 19 7	(Alluv. Tailings) ..	3,274 12 0	13,234 9 2	23,871 2 12	95,040 8 9
1866	59,573	19,775 16 0	0 6 15	78,584 19 1	..	6,438 15 6	26,171 7 4	26,214 11 6	104,756 6 5
1867	58,288	26,828 8 0	0 9 5	106,453 6 9	4,515	6,338 15 6	25,460 5 10	33,167 3 6	131,913 12 7
1868	63,057	28,250 3 12	0 8 23	111,625 2 11	..	423 14 12	1,652 7 6	28,673 18 0	113,277 10 5
1869	69,319	25,517 19 0	0 7 8	102,836 11 6	..	..	..	25,517 19 0	102,836 11 6
1870	55,240	13,441 0 0	0 4 20¾	54,418 17 0	..	..	..	13,441 0 0	54,418 17 0
1871	65,224	18,613 11 0	0 5 17	75,199 12 4	..	..	..	18,613 11 0	75,199 12 4
1872	66,299	15,706 19 0	0 4 17¾	63,671 1 4	..	611 6 18	2,459 12 9	16,318 5 18	66,130 14 1
1873	63,686	12,666 12 12	0 3 23½	51,738 11 4	11½	(Alluv.&Qtz.) 1,376 6 0	5,508 15 0	14,042 18 12	57,247 6 4
1874	61,021	12,402 5 0	0 4 1½	50,476 18 8	4,138¼	1,768 3 12	7,073 12 4	14,170 8 12	57,550 11 0
1875	42,356	10,516 11 0	0 4 23	42,658 4 11	4,134	2,572 2 3	10,406 4 11	13,088 13 3	53,064 9 10
1876	37,569	9,701 15 0	0 5 4	39,692 3 11	7,247½	4,631 1 6	18,848 15 8	14,332 16 6	58,540 19 7
6 months to 25th April, 1877	12,274	4,109 12 0	0 6 16¾	16,762 10 1	20,069½	7,545 15 12	30,722 7 7	11,655 7 12	47,484 17 8
	914,024	363,252 12 4	0 7 23	1,447,093 16 8	40,115½	44,355 16 3	178,435 4 3	407,608 8 7	1,625,529 0 11
6 months to 10th Oct., 1877	9,720	3,416 9 0	0 7 0⅔	14,005 13 10	21,206	9,201 8 0	37,699 19 2	12,617 17 0	51,705 13 0
	923,744	366,669 1 4	0 7 22½	1,461,099 10 6	61,321½	53,557 4 3	216,135 3 5	420,226 5 7	1,677,234 13 11
To 9th Oct., 1878	14,380	5,658 19 0	*	23,145 19 7	46,636	15,614 1 18	63,913 11 2	21,273 0 18	87,059 10 9
	938,124	372,328 0 4	0 7 22	1,484,245 10 1	107,957½	69,171 5 21	280,048 14 7	441,499 6 1	1,764,294 4 8
1879	7,183	3,569 8 0	*	14,590 10 2	46,221½	13,745 14 12	56,234 8 8	17,315 2 12	70,824 18 10
1880	2,127	1,828 11 0	*	7,471 18 9	39,040	10,560 5 0	43,214 0 11	12,388 16 0	50,685 19 8
	947,434	377,725 19 4	..	1,506,307 19 0	†193,219	93,477 5 9	379,497 4 2	471,203 4 13	1,885,805 3 2
Tributors	193,219								
TOTAL	1,140,653 tons								

* A good deal of this gold is from the pyrites saved from *all* the quartz crushed; the average per ton would not therefore be a fair one.

RETURN (No. 2) OF PYRITES TREATED.

Year.	Tons.	Gold.	Average.	Proceeds.	Profit.
1857-58 1859 1860 1861 1862	No pyrites saved during these years.				
		oz. dwt. gr.	oz. dwt. gr.	£ s. d.	£ s. d.
1863	562	467 7 0	Badly dressed	1,817 8 8	..
1864	76	201 0 0	2 12 9	749 18 6	417 0 0
1865	271	762 13 0	2 16 6	3,031 4 0	2,255 17 0
1866	268	796 8 0	2 19 4	3,169 7 9	2,131 17 10
1867	215	960 13 0	4 8 8	3,807 15 0	3,033 17 0
1868	369½	1,32[illegible] 13 0	3 12 4	[illegible],417 3 7	4,157 18 6
1869	401½	1,515 11 0	3 15 11	6,087 2 2	4,899 3 0
1870	456¾	1,420 6 0	3 3 6	5,732 2 2	4,571 18 0
1871	561	2,290 1 0	4 1 15	9,248 13 11	7,668 1 5
1872	368	2,061 9 0	5 11 22	8,522 11 8	7,208 6 9
1873	294	1,268 17 12	4 6 7	5,182 3 9	4,211 2 4
1874	330	1,024 0 0	3 1 22	4,178 6 2	2,770 8 9
1875	236¾	949 16 0	4 0 5	3,868 14 7	2,637 4 2
1876	224¼	937 7 0	4 3 14	3,819 13 9	2,687 18 1
Six months to 25th April, 1877	156	692 5 0	4 8 8	2,820 18 2	2,086 13 9
	4789¾	16,670 6 12	3 9 15	67,253 3 10	50,737 6 7
Six months to 10th Oct., 1877	165½	856 15 0	5 3 13	3,491 5 1	2,731 8 11
	4955¼	17,527 1 12	3 12 18	70,744 8 11	53,468 15 6
1878	399¼	1,935 7 0	4 16 23	7,886 11 0	6,144 7 0
1879	421	2,018 1 0	4 15 20	8,223 19 0	6,334 4 3
1880	390	1,625 2 0	4 3 8	6,624 1 5	5,028 10 6
	6165½	23,105 11 12	3 14 23	93,479 0 4	70,975 17 3

RETURN (No. 3) OF PERCENTAGE OF GOLD OBTAINED FROM—

Year.	Beds.	Boxes.	Blankets.	Mills.	Blankets and Mills.	Yield per Ton, Quartz, &c.
1857-58 1859 1860 1861 1862	The Gold during these years was not kept separate.					
						dwt. gr.
1863	66·33	23·33	10·34	..	..	11 9
1864	64·32	23·93	11·75	..	..	7 23½
1865	63·60	22·09	10·55	3·76	14·31	7 13¾
1866	65·60	21·63	8·73	4·04	12·77	6 15
1867	65·44	22·50	8·48	3·58	12·06	9 5
1868	63·22	24·03	8·11	4·64	12·75	8 23
1869	61·33	24·77	8·02	5·88	13·90	7 8
1870	60·15	26·69	2·74	10·42	13·16	4 20¾
1871	62·59	25·39	..	12·02	12·02	5 17
1872	64·48	21·60	1·06	12·86	13·92	4 17¾
1873	59·20	20·67	10·35	9·78	20·13	3 23½
1874	56·14	22·54	13·24	8·08	21·32	4 1½
1875	54·81	25·14	11·22	8·83	20·05	4 23¼
1876	58·17	21·24	11·12	9·47	20·59	5 4
1877	52·84	21·56	15·40	10·20	25·60	6 20¼
1878	52·84	17·12	17·11	12·93	30·04	7 20⅝

* A good deal of this gold is from the pyrites saved from *all* the quartz crushed; the average per ton would not therefore be a fair one.

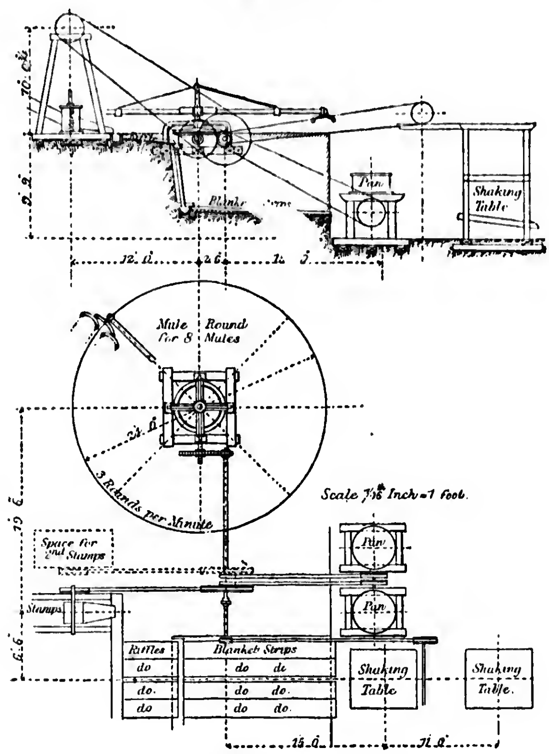
in sinking the north shaft near No. 9 level, and, though small, yielded well for two levels. The Old Man and Western lodes have continued the most defined in depth, and though very variable, continue to yield fairly.

"This mine was worked almost wholly on the contract system until 1874, when the tribute system was commenced, and has been continued to the present time, the results being more satisfactory to all parties interested in the mine.

"The miners have the opportunity of exercising skill and industry, and are paid in proportion to the results.

"(Signed) R. H. BLAND."

FIG. 176.



RIO GRANDE DO SUL CO.'S MILL.

Rio Grande mill.—Fig. 176 shows a gold-mill plant for mule power designed by Harvey and Co., Hayle, Cornwall, for the Rio Grande do

Sul Gold Mining Co., Brazil. The mill cost 730*l.*, and crushes 7 to 8 tons of gold-quartz per 24 hours. The weight of stamp-head is 160 lb.; diameter, 5½ in.; depth of shoe, 4½ in.; throw of crank, 8 in. The dimensions of the gratings are two 16¼ in. by 13¼ in., and one 16¼ by 11¾; the perforations number 144 per sq. in., and their diameter is 0·01 in. The number of blows per minute is 150; fall of head, 12 in.; weight of heaviest piece, 7 cwt.; framework, wood; water required, 2 cub. ft. per minute; power required, 8 mules.

CHAPTER VII.

AURIFEROUS ORES.

THE term "auriferous ores" is chosen for this chapter in preference to the more common one of "pyrites," for while pyrites properly includes only the sulphides of iron and of copper, there are many other metallic ores which carry gold as a secondary constituent. In a previous chapter (pp. 838–45), these ores have been catalogued in some detail, but it will be well to repeat here that they comprise the sulphides, oxides, arsenides, and carbonates of the following principal metals:—antimony, arsenic, bismuth, cadmium, chromium, cobalt, copper, iron, lead, manganese, tellurium, and zinc. Native silver is also always present in alloy with the gold. It may be said that there is not a single gold-mine in the world but what produces one or more of the metallic compounds alluded to in addition to its free gold, and consequently that the extraction of the gold from such ores is of universal importance: indeed many mines depend almost entirely upon "pyrites," and yield scarcely any free gold at all. This problem of the economical separation of gold from the ores of base metals is surrounded with difficulty, and has been the subject of much study and experiment. The results of these investigations it is proposed to discuss in the following pages; but first it will be necessary to ascertain the composition of these so-called "refractory" ores, and to examine the nature of the association between them and the gold.

Composition of ores.—

1. PORT PHILLIP (VICTORIA) PYRITES (Johnson and Matthey).

Gold	·035
Silver	·001
Arsenic	6·850
Sulphur	6·460
Iron, part in combination with the arsenic, sulphur, and oxygen, but chiefly in the metallic state	61·250
Silica	15·500
Oxygen	9·000
Water of combination, and loss	·904
	100·000

The gold = 11·425 oz., and the silver = 0·325 oz., per ton of pyrites.

2. Clunes (Victoria) Pyrites (J. Cosmo Newbery).

	1st.	2nd.
Silica	27·60	27·10
Oxide of iron (Fe_2O_3)	59·90	61·40
Sulphur	13·57	14·48
Lime	2·10	not estimated.
Carbonic acid	not estimated	

The mean results are 24·43 per cent. of iron-pyrites (FeS_2), and 44·35 per cent. of oxide of iron; this latter is present as ferric oxide (Fe_2O_3), magnetic oxide (Fe_2O_4), and as carbonate (Fe_2CO_3), with some sulphate. The gold=4 oz. 19 dwt. 23 gr. per ton of raw pyrites.

3. Mariner's Reef, Gympie (Queensland) Pyrites (Dixon).

Copper	17·02
Lead	2·01
Antimony	3·90
Gold and silver	0·22
Iron	31·41
Sulphur	37·86
Silica	7·16
Arsenic and loss	0·42
	100·00

The gold=12 oz. 10 dwt., and the silver=62 oz. 9 dwt. 16 gr., per ton of pyrites.

4. Grass Valley (California) Pyrites (J. A. Phillips).

Sulphur	46·700
Arsenic	0·310
Iron	41·650
Copper	trace
Gold	0·037
Silver	0·036
Silica	10·970
	99·703

The gold=12 oz. 2 dwt., the silver=11 oz. 16 dwt., per ton of pyrites.

5. Sonora (California) Pyrites (J. A. Phillips).

Sulphur	37·250
Arsenic	8·490
Iron	36·540
Lead	0·400
Gold	0·302
Silica	17·180
	100·162

The gold = 98 oz. 13 dwt. per ton of pyrites.

6. NORTH STAR (CALIFORNIA) PYRITES (J. A. Phillips).

Sulphur	43·720
Arsenic	1·360
Iron	39·250
Copper	0·220
Gold	0·026
Silver	0·012
Cobalt	0·150
Silica	14·230
	98·968

The gold = 8 oz. 10 dwt., and the silver = 3 oz. 18 dwt. per ton of pyrites.

7. COMSTOCK (NEVADA) ORES. *See* p. 175.

8. VICTORIAN ANTIMONIAL ORES.

Antimonial sulphide .. 33 to 65 per cent. | Gold .. 1 oz. 10 dwt. to 3 oz. 18 dwt. per ton.

9. MALDONITE. *See* p. 840.

10. RIO TINTO (SPAIN) ROASTED PYRITES (Gibbs).

* Copper	1·65
* Iron	3·64
* Sulphur	3·53
Cupric oxide	2·75
Zinc ,,	2·02
Lead ,,	0·47
Silver	0·0037
Cobaltic oxide	0·007
Bismuth ,,	0·013
Calcium ,,	0·20
Ferric ,,	77·40
Sulphuric acid	6·10
Arsenic ,,	0·24
Insoluble residue	1·45
	99·47

* Calculated as Cu_2S and Fe_2S_3. Gold in quantity too small to estimate.

11. THARSIS (SPAIN) ROASTED PYRITES (Gibbs).

* Copper	1·50
* Iron	3·23
* Sulphur	3·15
Cupric oxide	2·56
Zinc ,,	0·55
Lead ,,	0·70
Silver	0·0023
Cobaltic oxide	0·032
Bismuth ,,	0·010
Calcium ,,	0·25
Ferric ,,	77·00
Sulphuric acid	5·25
Arsenic ,,	0·17
Insoluble residue	5·85
	100·25

* Calculated as Cu_2S and Fe_2S_3.

12. SAN DOMINGOS (PORTUGAL) ROASTED PYRITES (Gibbs).

* { Copper	1·55
* { Iron	3·76
* { Sulphur	3·62
Cupric oxide	2·70
Zinc ,,	0·47
Lead ,,	0·84
Silver	0·0023
Cobaltic oxide	0·033
Bismuth ,,	0·013
Calcium ,,	0·28
Ferric ,,	78·15
Sulphuric acid	5·80
Arsenic ,,	0·25
Insoluble residue	1·85
	99·31

* Calculated as Cu_2S and Fe_2S_3.

13. YTTERŒN (NORWAY) ROASTED PYRITES (Gibbs).

* { Copper	1·01
* { Iron	3·33
* { Sulphur	3·10
Cupric oxide	0·39
Zinc ,,	6·46
Lead ,,	0·06
Calcium ,,	2·30
Ferric ,,	68·06
Sulphuric acid	6·56
Arsenic ,,	0·05
Insoluble residue	8·74
	100·06

* Calculated as Cu_2S and Fe_2S_3.

Association of the Gold.—Bearing in mind what has (pp. 746–803) been said on this subject, it seems to be generally agreed that the gold present in pyrites exists as metallic gold (though Prof. E. J. Chapman of Toronto asserts that the gold is present as an arsenide in the mispickel of North Hastings). At the same time, microscopic examination shows the gold to be an extremely finely-divided slate; and the evidence of Cosmo Newbery and Skey is to the effect that much of it is coated with a film of pyrites, so thin as to make no appreciable difference to the colour and lustre of the metal, yet sufficient to prevent its contact with the mercury, even after grinding. The want of uniformity in the opinions of the best authorities would seem to indicate that there is something yet to learn on this question of the nature of the association of the gold.

TREATMENT OF COMPLEX ORES.

As the characters of the ingredients composing an ore must necessarily govern the processes suitable for its treatment, it will be convenient to discuss the subject in detail under the heads of the chief components. In most cases, the process involves 3 operations—(1) disengaging the sulphur, arsenic, &c., (2) amalgamating the liberated gold, and (3) recovering some of the lost mercury.

ANTIMONIAL ORES.—The occurrence of gold in antimonial ores has been described on p. 838. From any of these it is possible to extract both the gold and the antimony. According to Cosmo Newbery, the following conditions are observed.

If antimonial ores are burnt in kilns or roasted in furnaces, either for the purpose of rendering the quartz more friable, or for getting rid of the antimony minerals, there is always a partial reduction, unless the heat is very great, and free access is given to atmospheric air. This reduction of ore producing metallic antimony is due to two causes—(1) the carbon of the fuel coming in contact with antimony oxide, either native oxide or that produced in the furnace by the oxidation of the sulphide, reducing it to a metallic condition; (2) by the action of the oxide on the sulphide, producing sulphurous acid and metallic antimony.

Metallic antimony has a great affinity for gold. It forms an alloy either when the two metals are melted together, or when the vapour of antimony is passed over heated gold. The alloy produced is grey in colour and very brittle, and amalgamates with mercury only after long contact and continual grinding, or by heating the two together. The amalgam, when formed, floats on mercury, and gradually gives up metallic antimony as a fine powder when agitated with water. This antimonial powder carries off a quantity of mercury and gold-amalgam entangled with it.

Antimony sulphide is perhaps the worst mineral with which the quartz-crusher has to deal. It divides the mercury into a black "flour" even more quickly than arsenical pyrites; and if this flour is triturated with the intention of bringing the globules of mercury together, a chemical combination takes place. The mass gradually changes colour, passing from the original blue-black or dark grey to a pure black, and then through brown to a brown-red. Upon examination, Cosmo Newbery finds that the remaining mercury contains antimony, and that the brown-red non-metallic portion consists of a mixture of undecomposed antimony sulphide and mercury sulphide.

Sodium amalgam he finds to be worse than useless in bringing together the globules of mercury floured by antimony sulphide. When only containing a small percentage of sodium, it has no action; when made stronger (sufficient sodium to cause a slight evolution of hydrogen when the mercury is placed in water), it decomposes, "the antimony sulphide forming sodium sulphide, an amalgam of antimony, mercury, and sulphuretted hydrogen." Sodium amalgam also reduces the metal from antimony oxide. If antimony sulphide is fused with finely divided gold, a portion of the gold enters into chemical combination with the ore, and is dissolved with the antimony sulphide in alkaline solutions. Antimony oxide has no effect on mercury or amalgam.

The process adopted by the Costerfield Co. for treating their ores, consisting of sulphide and brown and white oxides of antimony (see p. 839), is as follows. The portion of the ore free from quartz is picked out and set aside for smelting, the remainder being crushed to extract the gold. The tailings, which consist of antimony and a little quartz sand, are then conveyed to heaps, and are subsequently prepared for smelting by a process of buddling. A sluice-box, into which a stream of water is turned, is fed with tailings, which are made to pass thence on to a triangular tray forming an inclined plane, so arranged as to cause the water and tailings to flow over it in a broad shallow stream, into an oblong receiving-pit below; the purest antimony-ore, from its greater specific gravity, settles in the pit at the end nearest the tray; as the sediment recedes from this end, it gradually becomes mixed with an increasing proportion of sand, but much of the latter is carried away in the overflow of water from the pit.

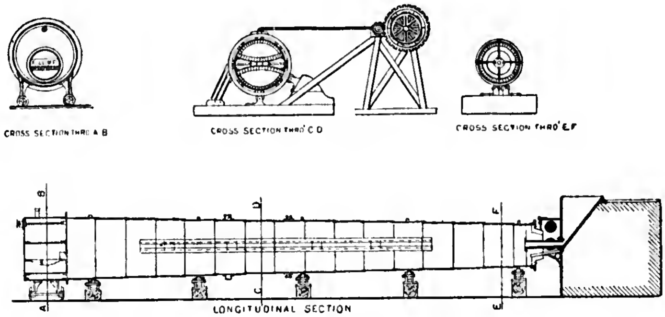
On cleaning out the receiving-pit, that portion of its contents containing quartz sand is returned to the heaps, to be again passed through the buddle, and the pure ore is collected in bags, and sent to the boiler-house to be dried; it is then placed in a smelting-furnace, with equal proportions of uncrushed ore, and reduced to crude antimony (sulphide), the slag and cinder resulting from this process being further treated by roasting or calcining in a reverberatory furnace to liberate the oxide, which passes off in fumes from both furnaces into the oxide flue; and as the fumes cool on their passage to the smoke-stack, the oxide is deposited in chambers constructed in the flue to receive it. The residue from the reverberatory furnace is afterwards crushed to extract any gold it may contain.

The gold obtained from the mineral defrays the whole of the company's working expenses, and the yield of crude antimony and oxide is clear profit; none of the latter has yet been brought into the market, but the shipments of rough ore hitherto sent to England have realised 9*l.* to 12*l.* per ton. The ore yields about 45 per cent. of crude antimony, which it is expected will fetch 20*l.* to 22*l.* per ton in London.

The revolving furnaces used in the foregoing operations were devised by H. Herrenschmidt and Borthwick, and treat 20 to 50 tons per diem. Herrenschmidt's is shown in Fig. 177. It measures 35 ft. long, 3 ft. in diameter at one end and 4 ft. at the other, and is made of $\frac{1}{4}$-in. plate.

The process adopted for treating auriferous ores containing antimony sulphide, by fusing the sulphide with a portion of metallic antimony, and using the same metal with fresh charges of the ore until it becomes rich in gold, and then separating the two metals by the oxidation of the antimony, while suitable for rich antimony-ores, will not answer for those

FIG. 177.



HERRENSCHMIDT'S REVOLVING FURNACE.

containing less than 30 per cent. of the sulphide, as they are too silicious to fuse. Hence very large quantities of the poorer auriferous antimony-ores do not yield half their gold to ordinary processes, and do not return any antimony when worked for gold.

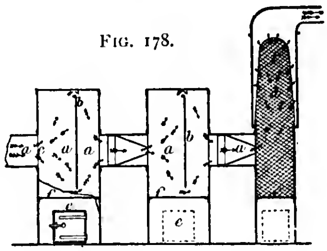
Cosmo Newbery has introduced the following method for treating such ores, which may also contain gold, silver, nickel, cobalt, sulphur, and arsenic. The uncrushed ores are placed in a kiln or furnace, with a quantity of salt sufficient to produce the amount of chlorine necessary to get rid of the sulphur, antimony, and arsenic. As soon as the calcination commences, a supply of steam or aqueous vapour is conducted to the bottom of the kiln or into the furnace, in such quantities as to keep the whole mass saturated. That it is so saturated is ascertainable by holding a condensing surface, such as a piece of cold iron, over the calcining mass: if the saturation is being effected, the surface will become damp. The saturation is continued until there are neither antimonial nor arsenical fumes, nor the smell of sulphurous acid or sulphuretted hydrogen. The process is then completed, and the charge is drawn; it is ready for any further treatment for extracting the precious metal.

A condenser for facilitating the solidification of the metallic vapours given off in these roasting processes has been perfected by Cosmo Newbery and John Lister Morley.

To accomplish this object, it is essential that the fumes should be directed with considerable velocity against a series of solid resisting surfaces, and finally against a web of permeable material, through which the permanently gaseous portion may filter. The greater the force with which such fumes impinge against a series of metallic discs, the larger is the percentage of solids which attach themselves to such discs, and ultimately fall into a receptacle beneath. Also, if such current of fumes is concentrated so as to be compelled to pass through a narrow opening, and then against a metallic disc, the effect is heightened. If the velocity of the current be great enough, that is to say if the draught be strong enough, by far the larger proportion of the solids will deposit themselves on striking the discs, leaving only a small portion to be retained by the final filter; whilst on the other hand, if the discs were removed, the whole of the solids would be retained by the final filter, but would give it unnecessary work to do.

This filter is made of metallic gauze, which may be protected from the action of the fumes by a coating of any non-volatile oxide infusible at the temperature which it is required to withstand. The mesh of this gauze is reduced to any requisite fineness by felting with asbestos or covering with asbestos cloth, or, when the fumes are sufficiently cool, with wool or vegetable fibre.

FIG. 178.



FUME CONDENSER.

An illustration of how an apparatus might be constructed for the purpose of carrying out this method is shown in Fig. 178. In the flues *a* are a series of resisting surfaces (discs) *b*, *c* being the orifices through which the gaseous current would flow and impinge on such surfaces, and *d* the final filter; *e* are the receptacles for the solids which fall after impinging against the discs, and which can be removed through a door *f* at the bottom. The necessary draught is produced by artificial means, although it does not matter how it is produced, so long as it is strong enough.

The apparatus is applicable to the condensation of fumes of antimony, arsenic, bismuth, lead, and zinc. The process is simple, inexpensive, and effective. The solid particles adhering to the plates, the arsenic, antimony, and other volatile oxides, form a dense cone of such solidity that the strongest current of air fails to dislodge any. Antimony oxide collected in this manner is well suited for the manufacture of paint, if the temperature of the fume has been lowered from the heat of the furnace in which it is generated till the vapour has been all condensed into solid particles of oxide in suspension. If the vapour of the oxide condenses on the plate, it is no longer suited for paint, being crystalline, and having no "covering" power when mixed or ground with oil. The arsenic condensed by this method should also be a marketable commodity, and, as crude arsenic, become of value to the pyrites worker, instead of a public nuisance.

Designolle's process.—Designolle's process is based upon the following grounds: (1) that when an acid solution of any salt of mercury is exposed to the action of an electric current, the salt will be decomposed, and metallic mercury will be deposited at the negative pole, amalgamation resulting when that pole is formed of gold; (2) when scraps of clean iron are in contact with a slightly acid solution of a salt of mercury, on touching these with gold, the salt of mercury is decomposed, metallic mercury combining with the gold; (3) the great affinity of chlorine for antimony and tellurium. Reasoning from these conditions, the process consists in using a bichloride of mercury solution in water containing sodium chloride, whereupon antimonial gold and the telluride of gold are decomposed, the chlorine uniting with the antimony and tellurium, while the liberated metallic mercury amalgamates with the gold.

ARSENICAL ORES.—Arsenic occurs largely in auriferous ores in combination with iron and sulphur (as arsenical pyrites, or mispickel), also as arseniates of lead, copper, and iron. From any of these minerals it may be easily set free in the roasting-furnaces and quartz-kilns, especially the latter, owing to the fuel, and the reducing gases produced by the imperfect combustion, coming into contact with these ores. When the arsenic is thus set free, it passes through the furnace as vapour, and is readily taken up by the gold that may be present; for when gold is heated to redness, or any degree between that and its melting-point, it takes up arsenic, with which it forms a grey, easily-fusible, brittle alloy; even when the arsenic is not in sufficient quantity to change the colour or fusing-point of the gold, it still renders it very brittle; one-thousandth part renders gold so brittle that it may be ground to a powder. Gold containing arsenic is more difficult to amalgamate than pure gold. If much arsenic is present, the amalgam is powdery and black, and floats on the surface of the mercury; the black colour is due to the separation of arsenic. This black powdery metallic arsenic does not unite at ordinary temperatures with mercury to form an amalgam, but it mixes with it, coating every globule with the black powder, thus preventing their uniting with each other, or, in other words, causing the mercury "to flour." Sodium amalgam aids the union of mercury floured by metallic arsenic; but if arsenious acid (common white arsenic) is present, it reduces it to the state of metallic arsenic.

Arsenical pyrites acts seemingly in the same way as metallic arsenic with mercury; when ground together, a large amount of black floured mercury is produced. If the pyrites is partly decomposed, this action is more energetic than with the original mineral. Cosmo Newbery can detect no actual combination with the mercury. The black coating, examined under the microscope, only seems to be a mixture of pyrites-grains and mercury-globules, both very finely divided. When mercury covered thinly with this black coating is warmed, the coating is absorbed into the mass, and is liberated again as the mercury cools.

The liberation of the arsenic from auriferous ores is most commonly effected by means of roasting them in furnaces of various construction, which will be now noticed, premising that Newbery's process described under Antimony (p. 1108) is equally applicable.

Chapman's process.—The following process was introduced by Prof. E. J. Chapman for treating the mispickel ores of Marmora (see pp. 79, 839). These ores contain 7 to 8 dwt. of free gold per ton, and a total of nearly 7 oz. per ton, but for a long time their treatment could not be made remunerative.

Chapman discovered that by deflagrating the ore with nitrate of soda, a most rapid absorption of oxygen takes place, and a large proportion of the arsenic at once combines with the nitrate of soda, and becomes soluble in hot water. The sulphur being burnt is, to a great extent, driven off, and the iron by absorption of oxygen rapidly becomes magnetic. The leachings of soluble arsenic subsequently obtained contain large quantities of sulphate of soda, which, rapidly depositing in a crystalline form, admits of the soluble arsenic being drawn off, precisely in the scale required for the manufacture of Paris green, when combined with sulphate or other salts of copper, in the ordinary manner. If the manufacture of orpiment is required, the arseniate of soda combined with sulphuretted hydrogen deposits a pigment of a beautiful yellow colour. In either case, the resulting bye-product is worth the cost of the materials used in the manufacture.

The process is carried out as follows. The ore, after being very finely ground, is sifted through fine wire sieves, so as to prevent the presence of any large particles. It has been found that whereas it will require 12 hours' roasting to expel the arsenic from a cube of ore $\frac{1}{16}$ in. square, if the cube be divided into 10 particles, one-tenth of the time will suffice. The sifted ore is mixed with 10 per cent. of its weight of nitrate of soda dissolved in water. The ore is then fed slowly into a peculiarly shaped iron retort, constructed in 2 half-circles, with flanges at each side, to withstand any tendency to warp, and also to form a resting-place for the retort when set in brickwork. The retort is 10 ft. long by 30 in. in diameter, cast in a peculiar manner, so as to avoid cracking and resist wear. It is set in brickwork, with an inclination towards its mouth of about 8 in. The fireplace is at the mouth, and the heat traverses the entire length of the retort, ascends at the rear, and passes forward and over the upper half, until it escapes into the chimney. The retort is thus enveloped in fire sufficiently powerful to keep the contents at a dull-red heat. The fuel required is not much, as the combustion of the sulphur and nitrate heats the ore to redness at once, and after it is hot, a very small fire will keep it so.

The ore, being fed into the rear end, gradually works its way downwards towards the mouth, each revolution of the internal machinery combining with the inclination to produce this effect. The machinery that generates this motion is a shaft that passes through the entire length of the retort, and is made to revolve half round by means of a crank attached to the projecting end; strong arms are fastened to the shaft, and attached to them are iron bars, so arranged that, as the shaft revolves half round, these bars scrape the bottom of the retort, and carry the ore to and fro, first to one side and then to the other, thus causing it to flow over each bar during each revolution in a thin stream of red-hot ore, much the same in appearance as a broad fall of water. This motion causes all the disengaged arsenic to pass off very readily. Arsenic in this state practically sublimes at about 500° C. (932° F.); but it condenses quite easily, and unless means are provided for its free disengagement, is a long time before it passes quite away into the condenser provided to receive it.

Being fed into a red-hot retort, the ore instantly deflagrates, and the furnace is filled with blue flame; some arsenic begins to pass over into the condenser, but a large proportion combines with the nitrate, and this portion becomes soluble in hot water, and can readily be removed by the filtration that takes place afterwards.

The speed of the shaft must be so arranged that the ore is delivered at the mouth of the retort in about ½ hour. As the ore leaves the retort, it falls—whilst red-hot—into water. The effect of this is to boil the water, to dissolve out the arsenic made soluble by the nitrate, as well as to burst the particles of ore and reduce them still further to a smooth paste, and thus render the gold more attainable. The liquor that results from the leaching rapidly deposits—in a crystalline form—quantities of sulphate of soda. The remaining liquid is now fit to yield Paris green, or orpiment, as required. After leaching, the ore is returned to the roasting-retort; this is very similarly constructed to that used for deflagrating, but, being set at a less inclination, the ore does not reach the mouth of the retort until it has had at least 2 hours' more roasting. The arsenic is now altogether driven off, the ore assumes a deep-red colour, and the iron having become magnetic and parted with all the arsenic, the combination no longer influences the amalgamation of the mercury and gold.

Cule finds that the old German barrels give the best results as amalgamators. Their action is greatly assisted by the use of steam, which Cule has applied in pipes that pass and repass through the barrel, and by the heat keep the ore always at about 212° F. (100° C.), consequently the mercury is kept quite limpid, and in that state will more readily catch the millions of minute particles of gold that pervade the prepared ore, and which have been loosened, so to speak, from amongst the other constituents of the mispickel, by the oxidation of the ore, and destruction of the combination of arsenic, sulphur, and iron that contained it. Cule also uses stones, and finds their action most beneficial in reducing the prepared ore to a still finer soft paste, and also in causing a certain abrasion or scouring of the surface of the particles of gold, rendered somewhat sullied by the roasting and nitrate, in which state the mercury does not so readily attack it.

Cule finds the result of all this to be : that mispickel ores that contain about 50 dwt. of gold to the ton can be readily made to yield at least 40 dwt.; that the bye-products, soluble arsenic, arsenious acid, sulphate of soda, and oxides of iron, are believed to be fully as valuable as the cost of manipulation of the ore, including mining, thus leaving the gold as almost all profit. As a further bye-product, the sulphurous acid fumes can be caught and condensed in chambers, and will be useful for the manufacture of superphosphate of lime. The nitric acid also will be forced into contact with lime, and a valuable manure will probably result from this course.

While admitting the probable increase of gold return by this process as compared with those in general use, Cosmo Newbery doubts its applicability in Australia, for the following reasons. Assuming the pyrites to contain 2 oz. of gold per ton, of which 80 per cent. (the Port Phillip Co. extract 95 per cent.) is recovered, this would mean a loss of 8 dwt. of gold per ton, worth (at 4*l.* per oz.) 32*s.* The amount of nitrate required is 2 cwt. per ton, costing 24*s.* a cwt. (infinitely more since the border difficulty in Peru and Chili), so that, excluding labour and fuel, the 32*s.* worth of gold would need 48*s.* worth of nitrate of soda, even supposing all the present loss to be saved. This loss of 16*s.* would have to be recouped from the sale of arsenical pigments, which have as yet no value in Australia.

Flude's furnace.—The author is indebted to Joseph Flude, Esq., Superintendent of Laboratories at the School of Mines, Ballarat, Victoria, for the following observations, and description of Serjeant and Flude's furnace :

"On all our gold-fields there is a considerable quantity of pyrites associated with the quartz, in some cases existing as sulphides, in others as arseno-sulphides. In order to extract the gold (which is always associated with the pyrites) from them, various methods have from time to time been devised; but at present the most popular, and, I think, the best, process is that of roasting to sweetness. This operation is performed by submitting them to a dull-red heat for a lengthened period under constant rabbling in long furnaces, the hearth of which is inclined at about

1 in. per ft.; the charge enters at the upper end and the fireplace is at the lower end of the furnace; the rabbling causes the charge to gradually descend the inclined hearth, so that when it approaches the bridge of the furnace it receives the greatest heat, and is finally discharged (by intermittently withdrawing a slide) through the hearth into a chamber under the bed of the furnace. By this method, when carefully conducted, the pyrites can be roasted to almost perfect sweetness, so that by a corresponding care in the after-manipulation, nearly the whole of the gold may be extracted.

"It may readily be seen that in such a furnace the sulphur and arsenic in the pyrites take fire, are converted into sulphur dioxide and arsenious oxide at the expense of atmospheric oxygen, pass away together with carbon dioxide from the fire, and escape at the top of the chimney-stalk into the air. The arsenic is more or less effectually condensed in a long horizontal flue, between the furnace and the chimney-stalk; these flues are opened at stated periods and cleaned out, and the arsenious oxide is deposited in any convenient place, so that it may be got rid of.

"There are at least two objections to this plan of operations: (1) all the sulphur and arsenic are lost; (2) it is injurious to health and vegetation, by polluting the surrounding atmosphere and streams of water.

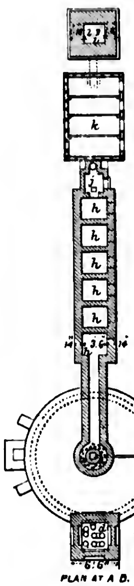
"The furnace to be described (Fig. 179) is a modification of the Brunton, and is intended to meet all objections to the furnaces as at present in use in Australia. It is almost automatic, being self-acting in so far as the feed and discharge are concerned, and, when set at work at the proper speed, is continuous in its operation; the only care required is to keep the hopper *a* supplied with the material to be roasted, consisting of pyrites which has passed through the stamper-box grating of say 100 apertures to the sq. in., and afterwards concentrated to nearly clean pyrites.

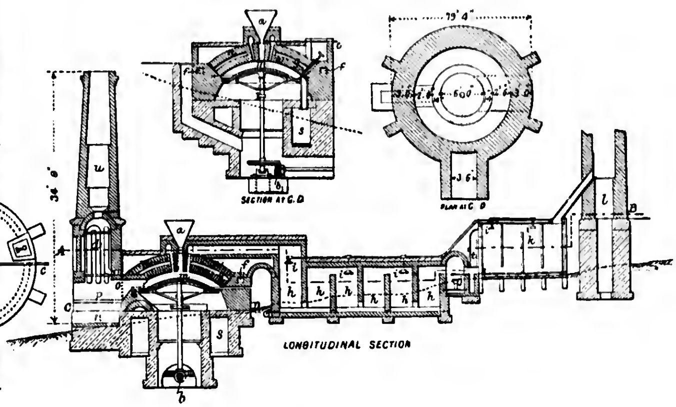
"The bed of the furnace is worked by belt and pulley on a shaft connected with the bevel-pinion *b*, and driven by the machinery which grinds and amalgamates the roasted pyrites. On the same shaft is another belt and pulley, which is intended to drive the self-acting feed-shaft *c*, the end of which passes through the throat of the hopper, so arranged that at every revolution a quantity of the pyrites is discharged into the furnace, sufficient to keep it supplied with fresh material, which, by the time it arrives at the periphery of the hearth, is completely roasted; thence it is discharged down fluming into a chamber below, where it is allowed to cool, and is passed into the triturating-machine.

"The novelty of this furnace consists in the fact that no fire passes over the materials when in course of roasting, but, instead, an abundant supply of heated air is used, which passes through heated pipes in a chamber *d* immediately over the fireplace, and cut off from the bed of the furnace by closing a strong damper in front of the fire-bridge *e*. The heated air from the pipes enters a flue *f*, which continues round the entire crown of the furnace, communicates at intervals with the chamber *g* in the crown, and leaves this chamber through perforations in the bricks, causing the air to impinge on the hearth; thus securing the thorough oxidation of the arsenic as arsenious oxide (As_2O_3), of the sulphur as sulphur dioxide (SO_2), and of the iron as ferric oxide (Fe_2O_3).

"The SO_2 and vapour of As_2O_3 pass into the chambers *h*, and the arsenic as arsenious oxide (As_2O_3) is condensed by means of steam-jets *i*, while the sulphur dioxide continues through the furnace *j*, where nitrous gas is generated; the mixed gases of sulphur dioxide, nitrous acid, and atmospheric air pass on into the sulphuric acid chamber *k*, where they finally become converted into sulphuric acid, the waste gases being allowed to escape up the chimney-stalk *l*.

FIG. 179.



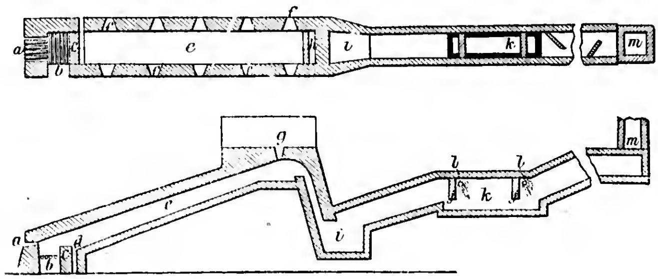


SERJEANT AND FLUDE'S FURNACE.

"The various parts are marked thus :—*a*, feed-hopper ; *b*, bevel-gearing to drive furnace-bed and feeding apparatus; *c*, shaft of self-feeder ; *d*, hot-air pipes over fireplace ; *e*, fire-bridge; *f*, hot-air flue communicating with chamber *g* ; *g*, chamber in crown of furnace ; *h*, condensing chambers for arsenic ; *i*, steam-jets ; *j*, small oven for generating nitrous gas; *k*, leaden sulphuric-acid chamber ; *l*, chimney-stalk, 62 ft. high ; *m*, furnace hearth ; *n*, furnace crown ; *o*, damper ; *p*, fireplace ; *r*, ash-pit ; *s*, chamber to receive roasted pyrites ; *t*, flue for passage of mixed gases into sulphuric-acid chamber ; *u*, chimney-stalk of furnace ; *v*, discharge.

Port Phillip Co.'s furnace.—The reverberatory furnace used by the Port Phillip Co. for treating their arsenical pyrites is of the simplest description, as illustrated in Fig. 180. *a* are air-tubes for admitting air above the fire; *b*, fireplace; *c*, fire-bridge; *d*, discharge slot for burnt pyrites; *e*, roasting hearth; *f*, holes for insertion of a spade-bar to turn the pyrites over; *g*, hopper for charging pyrites into the furnace; *h*, flue descending to the pocket *i*, where heavy condensable matters deposit;

FIG. 180.



PORT PHILLIP CO.'S FURNACE.

j, stops for checking the flow of gases; *k*, leaden cistern wherein the arsenious vapours can condense, the operation being aided by the spray-pipes *l*; *m*, chimney for final escape of uncondensed vapours.

This furnace is perhaps better known as Latta and Thompson's, from the names of its inventors. It requires only one attendant per shift, and the labour may be reduced by making the furnace in 3 sections at right angles to each other, so as to facilitate the operation of working the charge through. The roasting must be continued till all the sulphur and arsenic are driven off, and the pyrites becomes "sweet"; but the heat must not be carried too high, nor is it necessary to convert all the iron present into sequioxide. The time occupied in the process is 12 to 18 hours, but efficiency must not be sacrificed to time, for partially decomposed pyrites causes more flouring of the mercury, and greater loss of gold and amalgam in the subsequent stages, than when raw. The sweetness is judged by the roasted material emitting neither odour nor fumes, by its giving off no sparks while hot, by its turning red when cold, and by its ceasing to run easily when stirred. About 4 to 4½ tons of pyrites per diem can be treated in such a furnace. The consumption of fuel will depend much upon the regularity of the stoking. Great attention must be paid to the draught of the furnace, as it is essential that a steady current of air should pass over the surface of the pyrites, to ensure thorough oxidation. Opinions are divided as to whether the presence of a small percentage of sand with the pyrites is detrimental or beneficial: on the one side, it is maintained that the sand tends to check the agglutination or caking of the particles of pyrites, which, when once begun, makes it very difficult, if not impossible, to roast properly; on the other hand, it is contended that the sand cuts up the mercury, and causes a great loss in the subsequent process of amalgamation, especially if a Chilian mill is used. Mixing charcoal with the pyrites in roasting promotes its decomposition by the combination of the sulphur with the carbon; but a good furnace properly attended requires no such aid, and when lead or antimony is present in the pyrites, the carbon acts injuriously by reducing the metals from their ores.

The second step in the treatment is to grind and amalgamate the calcined ore in the pan of a large Chilian mill (see p. 1038). Mercury is added for this purpose, and the grinding helps to break up the mercury and bring it into contact with the liberated gold particles.

The third stage is the collection of the particles of gold, mercury, and amalgam escaping from the mill. This is effected by passing the whole through a concentrator, or even two in succession, and then through a mercury-trough and amalgamating-barrel, the tail-sand being run through buddles. By these means, as high as 95 to 98½ per cent. of the gold in the pyrites has been extracted.

The following results were obtained with the pyrites treated at the Port Phillip works for the year ending Oct. 10, 1877:—

Pyrites, raw	321 tons 10 cwt.
Gold produced	1549 oz.
Average per ton (raw)	34 oz. 16 dwt. 9 gr.

Loss in weight roasting, say 20 per cent.

Costs per ton—	£	s.	d.
Buddle expenses	1	1	8
Roasting—Labour, 13*s.* 3*d.*; fuel, 9*s.*	1	2	3
Grinding, labour	0	13	3
Mercury lost, 1 lb. 6½ oz., value	0	4	3
Total cost per ton	3	1	5
Cost per oz. of gold obtained	0	13	2

Mercury and gold recovered in the steam barrel for 8 months in use—Mercury, 185 lb.; gold, 55 oz. 5 dwt.

At the Walhalla Co.'s works, the same treatment with slight alterations was introduced in July 1868 and carried on until February 1876. During that time, 1411 tons of raw pyrites, yielding 942 tons of calcined ore, were treated, which returned 2476 oz. 11 dwt. 6 gr. of standard gold, or at the rate of 2 oz. 12 dwt. 14 gr. per ton of calcined ore; the loss of mercury being 1839½ lb., that is 1·92 lb. per ton of calcined ore.

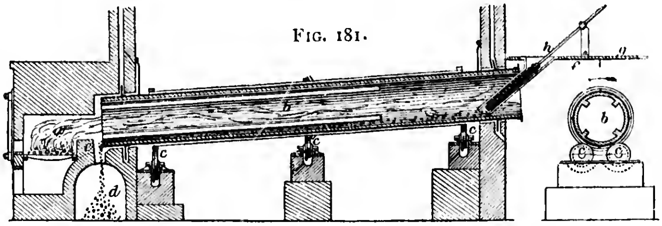
The cost of roasting the ore and other incidental expenses connected therewith was—

	s.	d.
Firewood	13	0
Wages	16	7
Repairs, cleaning flue, &c. ..	4	2
	33	9

It may be incidentally mentioned that while the average standard of the vein-stone gold of Walhalla is $20 \cdot 1\frac{5}{8}$ to $20 \cdot 1\frac{7}{8}$ carats, the gold from unroasted pyrites is only $19 \cdot 3\frac{7}{8}$ to $20 \cdot 0\frac{3}{8}$ carats, whereas that from roasted pyrites is $22 \cdot 0\frac{4}{8}$ to $22 \cdot 1\frac{1}{8}$ carats.

Revolving furnaces.—The inclined reverberatory furnace requires a considerable expenditure of labour for passing the charge through, hence several forms of mechanically revolving furnace have been introduced. Hocking and Oxland's may be described as typical of this kind of furnace. It is shown in Fig. 181, and consists of a fire-box *a*, whence

Fig. 181.



Hocking & Oxland's Reverberatory Furnace.

the heat and products of combustion pass through an iron tube *b*, made of boiler-plate and lined with fire-bricks on edge. The tube, which is 30 to 40 ft. long, is supported in an inclined position, but varying in inclination according to the character of the ore treated. It is supported on 3 pairs of friction-wheels *c*, and rotated by gearing in the middle. It passes into the fire-chamber, and is so arranged as to deliver the ore passing through it by an opening *e* into the chamber *d*. At the upper end it communicates with flues or condensing chambers *f*, and the ore is dried on cast-iron plates *g* covering these chambers, being fed into the hopper *h* by a boy who attends to the fire. The tube revolves at a rate of 3 to 8 revolutions per minute. The ore is raised by 4 projecting lines of bricks parallel with the axis, leaving room for the continuous running-in of the dry ore from the hopper. When the ore has been raised sufficiently high on one of these shelves, it falls off in thin streams through the hot gases passing up the tube. It thus becomes sufficiently heated for the sulphur and arsenic to take fire, and to burn with such energy that before the ore arrives halfway down the cylinder, the greater portion of the arsenic and much of the sulphur is driven off. The heat evolved by the combustion of arsenic and sulphur is thus rendered available for heating the upper portion of the tube. Throughout the whole of the tube, the lines of shelf perform the duty of passing the ore in finely-divided streams through the heated gases in such a way that no particle can escape full exposure to the oxidizing influences required for perfect calcination. It is found that arsenic burns first, and that its removal is completed some time before the last portions of sulphur are eliminated. The calcined ore, passing from the lower end of the tube into the burnt-ore chamber at a bright-red heat, contains only traces of arsenic, and but a small proportion of sulphur.

Rosales' process.—In the belief that the expenditure for roasting the pyrites, as just described, was unnecessary for the liberation of the gold, Henry Rosales, the talented manager of the well-known Walhalla mine, experimented in the direction of treating the pyrites by fine mechanical subdivision without roasting. The outcome of his experiments was the successful plan now to be described from documents very obligingly furnished by him to the author.

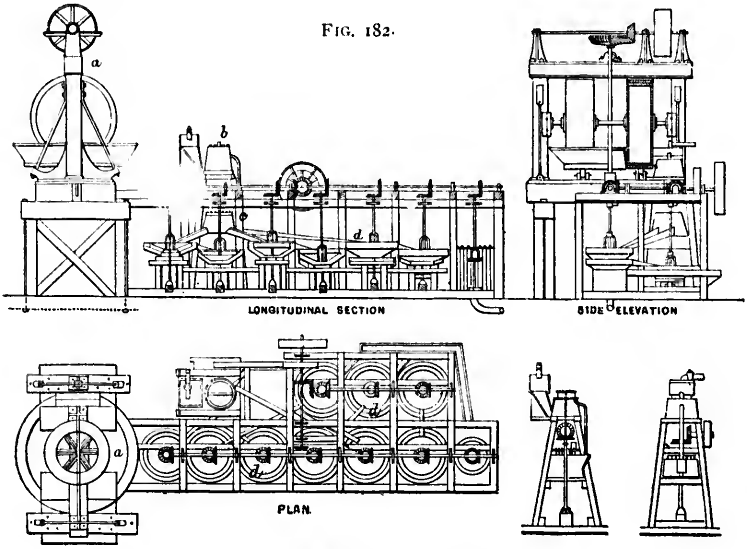
The mode of operation without roasting is—(1) to grind the pyrites to a fine pulp, in a Chilian mill for instance, and (2) to amalgamate in separate vessels, such as dollies, in conjunction with improved Tyrolese or Hungarian mills. At the Walhalla Co.'s works, the process is worked in the following manner. (See Fig. 182.)

The concentrated pyrites, which has been exposed to the action of the atmospheric air* during 3 to 6 months, and consists mainly of iron-pyrites (FeS_2), arsenical pyrites, mispickel (FeS_2+FeAs_2), and more or less quartz-sand, is subjected to grinding in a Chilian mill *a* (the rollers of which are 18 in. wide, making 13½ revolutions per minute) to a very fine state of disintegration. This is effected in the following manner. The charge, consisting of 3½ buckets of dry pyrites, weighing 107 lb., is, after 7 pints of water (less if the stuff is a little moist) have been filled into the pan, gradually emptied into the pan whilst it is revolving. Should the stuff be too dry, and the rollers run on top of the pyrites for more than 2 minutes, ¼ to ½ pint of water is slowly poured on until the rollers get on the bottom of the pan, which should be the case about 5 minutes after the charge has been put in. The main thing after this is to keep the stuff well together, forming a ridge in the middle of the pan by self-adjusting scrapers placed on each side of the pan and of the rollers, and also

* This exposure might be supposed to cause a considerable oxidation of the pyrites, but Rosales assures the author that in this case it is not so, there being no appreciable change in the composition, though the pyrites suffers a physical change which allows it to be ground to a much finer and softer pulp.

scraping with a shovel those places which the scrapers have failed to clean. About ¼ hour after the charge has been working, 2 oz. of caustic soda are distributed in the pan. After one hour's grinding, when the stuff commences to get stiff, 3 to 3¼ half-pints of water are added at different times during the last 1½ hour that the stuff is being ground. For the last 15 minutes, if the stuff has been properly attended to, its appearance is a fine pulp having a glossy and silky appearance. It is then ready to be shovelled out of the pan. But until its appearance is glossy and silky, the charge should not be taken out, as it would not be sufficiently ground.

Fig. 182.



Rosales' Mechanical Process.

The ground stuff is shovelled into a tub, where it is kept in a moist and pasty state, not too stiff, and whence it is passed on to a basin standing on a grating of 81 holes to the sq. in., through which it passes with a stream of water delivered into the basin, at the rate of 36 gal. per minute, and is conveyed into the top force dolly *b*, which is charged with 60 lb. of mercury, and revolves at the rate of 33½ revolutions per minute. Each charge is passed into this dolly from the tub in 2½ hours in regular proportions of about ¼ shovelful at a time, so that the stream of 36 gal. of water per minute should hold in suspension and carry with it about ¾ lb. of pyrites per minute.

From the top dolly, the stream flows into the bottom of the lower dolly *c*, which is also charged with 60 lb. of mercury, and revolves at the same speed as the upper one. The overflow or the stream from the lower dolly is divided into three sets of three Tyrolese mills (see p. 1041) each *d*, which are placed one below the other. Each mill is lined on the working surfaces with amalgamated copper-plates, and is charged with mercury to the lower edge of the copper-plates, which requires 27 to 35 lb. of mercury. The runner revolves at the rate of 19¾ revolutions per minute, and is set so that the bottoms of the arrows are ⅛ in.—i. e. 2½ to 3 turns of screw on the spindle—above the mirror of the mercury. Thus the stream passing through each set of Tyrolese mills is equal to 12 gal. of water, carrying ¼ lb. of ground pyrites with it.

To ensure the proper working of the mercury in the dollies and mills, sodium amalgam is used at the rate of 2½ lb. per 10 tons of dry pyrites treated: that is to say, 4 oz. per ton. A small quantity (about the size of a pea) is dropped every 8 hours into the mercury of each of the lower Tyrolese mills, and slightly more into that of the upper ones and of the dollies. The waste water from the third Tyrolese mill of each set flows into the creek. This company, unfortunately, has no convenience to erect settling-pits, &c., to catch the waste pyrites; but where convenient, and especially in a large establishment, it might be advantageous to save the waste pyrites for after-treatment, as, owing to insufficient grinding, a certain percentage of comparatively coarse pyrites could thus be saved.

As described, charge after charge is ground and subsequently run through the amalgamating-mills during one working month—26 days. Every day, however, the light dross amalgam, which does not sink into but floats on the surface of the mercury of the two dollies, is removed, together with the heavier and not sufficiently-ground pyrites. The dross amalgam or alloy is washed out in an enamelled dish, and kept by itself until the end of the month, whilst the pyrites that has been removed is at the end of the month re-ground with the last charges. The quantity of pyrites thus daily collected is only one-third of an enamelled bucket, about 15 to 20 lb., if the stuff has been well ground. At the end of every month, all the dollies and Tyrolese mills are emptied, washed, and the mercury of each dolly and mill separately collected, passed through a chamois-leather bag, and the amalgam in each case separately retorted. The returns obtained for several months are as per table on pp. 1122–3. From its perusal, it is obvious that whenever the ore has not been sufficiently ground—be it on account of the mill not grinding well, or because it was attempted to pass through too heavy a charge in a given time, or that too little water was passed, or that too much ore was rushed through the Tyrolese mills—a loss in mercury and gold was the immediate result, as shown by comparing the returns for the months of February and March, 1877, with those of the other months. As a proof

STATEMENT OF RETURNS

	Dry raw pyrites.	Alloy.		Upper Dolly.				Lower Dolly.				First set Tyrolese Mills.				Second set Tyrolese Mills.			
		Amalgam.	Retorted Gold.	Amalgam.	Retorted Gold.	Mercury Charged.	Mercury Recovered.	Amalgam.	Retorted Gold.	Mercury Charged.	Mercury Recovered.	Amalgam.	Retorted Gold.	Mercury Charged.	Mercury Recovered.	Amalgam.	Retorted Gold.	Mercury Charged.	Mercury Recovered.
1876.	ton c. qr. lb.	oz. d.	oz. d.	oz. d.	oz. d.	lb.	lb.	oz. d.	oz. d.	lb.	lb.	oz. d.	oz. d.	lb.	lb.	oz. d.	oz. d.	lb.	lb.
July } August }	10 2 0 14	14 14	6 18	13 3	4 14	60	62	2 12	0 16	60	61	14 14	4 0	50	49½	18 16	5 7	70	68½
August } September }	10 6 3 26	17 19	6 19	12 0	3 9	60	60	5 10	1 15	60	60	18 1	5 11	50	50	21 2	5 9	70	70
September } October }	10 4 3 3	16 6	7 1	6 17	2 0	60	65	2 13	0 13	60	59	16 17	4 8	50	50	13 4	3 16	70	70
October } November }	12 8 0 25	21 10	9 18	5 4	2 3	60	60	5 9	1 7	60	56	19 10	7 17	50	50	25 6	4 2	70	70
December ..	9 9 0 18	21 9	9 18	7 2	2 5	60	61	6 12	2 8	60	54	12 16	3 5	50	51	14 10	3 7	70	72
1877.																			
February ..	10 16 2 15	32 2	13 0	11 5	3 5	60	62	2 4	0 12	60	48	12 9	2 5	50	47	7 0	1 12	70	70
March ..	8 1 1 7	23 10	10 0	5 9	1 12	60	66	1 9	0 10	60	40	5 16	0 19	50	50	3 2	0 15½	70	70
June ..	14 6 2 14	37 0	15 8	8 4	2 13	60	60½	5 0	1 15	60	63	16 9	5 1	77	77	22 1	6 9½	97	97
July ..	10 3 2 27½	27 0	12 15	8 18	3 2	60	60	1 13	0 10	60	61	9 17	3 5	77	76	10 2	3 5	97	97
August ..	10 10 1 5	27 18	13 1	11 13	3 14	60	61	2 2	0 13	60	60	11 12	3 19	77	77	9 10	2 19	97	96
September .	9 1 1 19	22 8	10 7	10 8	3 5	60	60	2 13	1 1	60	60	7 4	2 2	77	70	9 2	2 17	97	97
October ..	10 2 1 10	20 12	10 13	11 12	4 3	60	60	2 10	0 18	60	60	8 3	2 15	77	77	11 5	3 8	97	96
1878.																			
March ..	15 6 3 13	30 2	11 5	11 10	3 10	60	66	3 6	0 18	60	60	12 6	3 9	77	75	14 4	3 16	97	93
April ..	8 11 3 3	21 2	8 12	8 10	2 10	60	60½	2 9	0 13	60	60	8 4	2 5	77	77	9 2	2 15	97	97
May ..	2 10 3 0	8 1	..	8 3	..	60	60	0 14	..	60	60	2 1	..	77	77	2 17	..	97	97
June ..	7 4 1 14	20 10	9 15	3 13	1 15	60	61	1 10	0 10	60	60	4 15	3 6	77	76½	4 11	..	97	97
July ..	9 4 3 7	28 13	14 2	10 13	4 12	60	62	2 4	0 13	60	60	9 12	3 0	77	77	9 12	2 19	97	97
August ..	10 10 1 18	27 0	11 9	3 17	1 11	60	61	1 15	0 11	60	60	8 4	2 10	77	77	10 7	2 19	97	97
August 30	9 5 1 9	29 2	11 19	5 17	2 8	60	60	2 16	1 1	60	60	11 5	3 4	77	77	9 13	2 12	97	97
	117 18 3 0								9 3				34 16				33 19		

* New bottoms. Too little water, dry season, and insufficient grinding.

† Recovered some mercury from last parcel. Reduced the charge from 3½ to 3¼ buckets. Grinding same time.

‡ ½ lb. lost actually, one of the mills working too close.

§ The quantity of silver not yet returned.

FROM ROSALES' PROCESS.

Third set Tyrolese Mills. Amalgam.	Third set Tyrolese Mills. Retorted Gold.	Third set Tyrolese Mills. Mercury Charged.	Third set Tyrolese Mills. Mercury Recovered.	Total Amalgam.	Total yield of Gold.	Average per ton of Raw Pyrites.	Total Return of Silver.		Sodium used.	Total Mercury charged including Sodium.	Mercury recovered from retorted Amalgam.	Total Mercury recovered.	Mercury lost.	Caustic Soda.	No. of buckets at 33 lb. per charge.	Hours ground.	Total Standard Gold.	Average Assays by Amalgamation.	Total Value of Gold.
oz. d.	oz. d.	lb.	lb.	oz. d.	oz. d.	oz. d.	oz.	s.	lb.	lb.	lb.	lb.	lb.	lb.			oz. d.	oz. d. gr.	£ s. d.
..	..	..	..	63 12	21 15	2 2⅝	..	..	6	246	3	244½	1½	abt. 25	2¼	2	19 10^{22}	2 9 13	75 5 0
..	..	..	..	74 12	23 3	2 4¾	..	..	5	245	3½	243¾	1¼	26	2½	2	20 9^{12}	2 1 0	78 16 9
..	..	..	..	55 17	17 18	1 15	..	..	6	246	2¼	246¼	..	26	2½	2	16 3^{5}	1 9 20	62 4 4
11 7	2 7	52	56	88 6	27 14	2 3¼	..	..	6	298	4	296	2	55	3¾	2	24 15^{14}	2 11 20	94 3 3
12 10	3 9	52	53	74 19	24 12	2 12⅛	..	..	3½	295½	3½	294½	1	47	3¾	2¼	20 19^{12}	2 4 8	80 15 11*
3 14	0 19	52	52	68 14	21 13	2 0	..	..	4½	296½	3	282	14½	50	3¾	2¼	18 6^{7}	..	70 10 6*
2 8	0 12	52	52	41 14	14 8½	1 15¾	..	..	4½	296½	1½	279½	17	40	3¾	2¼	12 17^{2}	..	49 9 9*
13 12	4 1½	79	79	102 6	35 8	2 7¾	3⅓	16	3¾	376¾	4½	381	..	70	3¼	2¼	31 16^{14}	..	123 6 9†
9 1	3 0	79	79	66 11	25 17	2 10¼	2⅝	12	2½	375½	2⅝	375⅝	⅛	25	3¼	2½	22 13^{21}	..	87 19 5
7 16	2 9	79	79	70 11	26 15	2 11⅙	2⅜	13	2½	375½	2¾	375¼	‡	26	3¼	2½	23 18^{18}	..	92 16 2
7 10	2 4	79	79	59 5	21 16	2 8⅞	2	10	2	375	2¼	374¼	¼	22	3¼	2½	19 10^{7}	..	75 12 7
8 16	3 1	79	79	62 18	24 18	2 9⅓	(?)	..	2	375	2½	374½	..	25	3¼	2½	22 6^{11}	..	85 18 10§
12 3	3 10	79	77	83 11	26 8	1 1$\frac{1}{11}$	..	..	3	376	3¾	374¾	¼	37	3¼	2½	22 11^{17}	..	90 16 0
6 15	2 1	79	79	56 2	18 16	2 4$\frac{11}{14}$	..	..	2	375	2¼	374¼	..	21	3¼	2½	17 0^{9}	..	65 10 5
1 7	..	79	79	23 12	8 7	3 5⅛	..	..	1	374	1	374	..	21	3¼	2½	7 5^{3}	..	27 18 9
3 18	..	79	79	38 17	14 16	1 15$\frac{11}{14}$	..	..	2	375	abt. 2	375¼	..	18	3¼	2½	13 2^{17}	..	50 11 4‖
8 8	2 11	79	79	69 2	27 4	2 18¾	..	..	2¼	375¼	3	378¶	3**	23	3¼	2½	24 9^{5}	..	94 3 6
9 5	2 15	79	79	60 8	21 4	1 16$\frac{29}{34}$	..	..	3	376	2¼	376¼	..	29	3¼	2½	18 18^{11}	..	72 17 4††
8 7	2 7	79	79	67 0	22 10	2 8$\frac{11}{14}$	..	..	2	375	3	376	..	24	3¼	2½	19 13^{8}	..	75 14 4‡‡
	27 19					2 6^{9}													

‖ Skimmed pyrites not put through.
¶ The surplus from old barrel pyrites. The skimmed pyrites of this and last month were put through.
** Gained.
†† Skimmed pyrites not put through.
‡‡ The skimmed pyrites of this and last [illegible]th were put through.

of the very satisfactory manner in which these improved Tyrolese mills work, it may be pointed out that of 105 oz. 17 dwt. of gold, which, since inclusive June 1877—the period during which the process worked most satisfactorily—passed through the second dolly, charged with 60 lb. of mercury during the treatment of 118 tons of pyrites, only 9 oz. 3 dwt. of gold were returned by the second dolly, whilst the

1st set of Tyrolese mills returned	.. ..	34 oz. 16 dwt. of gold.
2nd ,, ,,	.. ..	33 ,, 19 ,, ,,
3rd ,, ,,	.. ..	27 ,, 19 ,, ,,
Total from the 3 sets	.. ..	96 oz. 14 dwt. of gold.

That is, that of 105 oz. 17 dwt. which passed through the second dolly, it only saved 9 oz. 3 dwt. (8·5 per cent.), whilst the balance, viz. 96 oz. 14 dwt., was recovered by the three sets of Tyrolese mills, most of which, no doubt, would have been lost had the stuff been passed through even a third dolly.

Taking the return of gold for the last 5 months, it is plain, since by roasting the pyrites lose 33·3 per cent. in weight, that the yield per ton of calcined ore must be computed at one-half more gold than that returned per ton of raw pyrites; that is, that the yield of standard gold for 54 tons 4 cwt. 1 qr. 19½ lb. of raw pyrites having been at the rate of 2 oz. 4 dwt. 8 gr. per ton, the return per ton of calcined ore would be equal to 3 oz. 6 dwt. 12 gr.—an average which was not obtained by the calcining process, the return having been, as already stated, only 2 oz. 12 dwt. 14 gr., notwithstanding that the pyrites was clean, very well calcined, and was obtained from richer stone than that from which the 54⅕ tons just mentioned, were obtained.

But, besides a larger percentage in gold, the new process saved 10⅛ oz. of fine silver, value 2*l.* 11*s.*, whilst by the calcining process hardly any silver is returned, at least of any commercial value. This in a great measure explains the higher standard of the gold obtained by the latter process.*

* The following are probably the reactions that take place during the calcining process in the roasting-furnace, and explain how a certain quantity of silver is lost, and the gold obtained from pyrites is of a higher standard if calcined previous to amalgamation in the Chilian mill, than that obtained from pyrites not roasted previous to amalgamation. During the first hours that the pyrites is exposed to an oxidizing fire—roasted—the nascent sulphur, the presence of which is evidenced by the blue flames which constantly break through the charge, acts directly on the finely-diffused particles of argentiferous gold, abstracting a certain portion of, if not all, the silver from them, forming sulphide of silver, which is subsequently, towards the end of the roasting process, altered into a soluble sulphate of silver, the temperature not being sufficient to change the sulphate of silver into an oxide, much less into metallic silver. On treating and amalgamating the thus roasted pyrites, grinding it wet in the pan of the Chilian mill, the soluble sulphate of silver is washed out and carried off with the refuse; and thus occurs the loss of silver, whilst, on the other hand, its loss causes the gold obtained to be returned of a higher standard than it was when first charged in the furnace, in its original state.

It may be that in those localities where large quantities of pyrites are treated annually in a central establishment, to which the cost of transit from the mines is almost nominal, where the cost of machinery, materials for building furnaces, stores, fuel, &c., is low ; where good and cheap labour can be obtained, and where all the bye-products produced, such as sulphuric acid, white arsenic, sulphur, realgar, &c., can be readily sold at a profit ; that the calcining process and the subsequent amalgamation or chlorination or smelting of the roasted ore in conjunction with other ores would be the more remunerative process, and technically would perhaps be the more perfect ; but Rosales claims for the new process the following advantages as regards the treatment of ordinary pyrites (iron- and arsenical pyrites), viz. :—(1) That the pyrites at present allowed to run to waste can easily be treated in small parcels on the premises of any mining company situated in a mountainous district, or any other locality difficult of access, as (2) no calcining-furnace is required, the erection of which requires costly materials, not easily to be had in such places ; (3) that the cost of manipulation is less than that of the system now in vogue, which requires that the ore should be previously calcined in a reverberatory furnace, although the bye-products are valueless. (4) *a*, that a larger average yield of gold is obtained per ton of ore ; and *b* that a certain quantity of silver is obtained, which is lost by the ordinary calcining process. (5) That the loss of mercury is practically nil, whilst by the old process it varies from 1¾ lb. to 2 lb. per ton of calcined ore.

The Chilian mill used by Rosales is an improvement upon the Peruvian *trapiche* and on the edge-runner mills of Real del Monte and Yendelaeneina in Spain, in that the two rollers are provided on the outside face with a rim of white metal, and work on a revolving cast-iron pan fitted with a white-metal false bottom, made in sections, which can easily be replaced when worn out. The improvement in the Tyrolese mills consists in the addition of metallic surfaces coated with mercury to the faces of both runner and basin.

BISMUTH.—The occurrence of auriferous bismuth-ores is comparatively rare (see p. 840). Bismuth alloys readily with mercury, but does not seem to be so detrimental as antimony or arsenic. The sulphide causes the mercury to separate into "flour," and gives rise to loss in the same way as other sulphides. The sulphide of bismuth found at Maldon, though containing up to 20 per cent. of gold, does not give it up to mercury when triturated with the latter.

COBALT AND NICKEL.—Cosmo Newbery's process for antimony-ores, described on p. 1108, embraces also the separation of cobalt and nickel as chlorides. When they are associated with sulphur, arsenic, or antimony, these latter are first removed by roasting ; when the cobalt and nickel are free from these associations, the ores are first pulverized or calcined, then sufficient salt is added according to the assay, and the whole is roasted in the presence of aqueous vapour till the cobalt and nickel are converted into chlorides.

COPPER.—Copper is not injurious to the operations of recovering gold from pyrites, except in reducing the standard of the gold with which it is alloyed. On the other hand, by becoming amalgamated with mercury, it may actually assist in collecting the fine particles of metal, in the same way as amalgamated plates.

In dealing with auriferous ores containing copper, it should be borne in mind that in some cases the copper- and magnetic pyrites are almost free from gold, which is confined to the ordinary iron- and arsenical pyrites. In such circumstances, careful mechanical dressing of the ore might separate the auriferous non-cupreous from the cupreous non-auriferous portions, and each class could be treated alone for its particular metal. But in other instances, the association and relative proportions of the two kinds of pyrites do not admit of such a classification ; and again, the cupreous pyrites are sometimes the most highly auriferous.

Under these latter conditions, metallurgical treatment must be resorted to. The most simple plan is to smelt the ore, and produce a copper regulus, which will contain most of the gold, sending the regulus to Swansea for final treatment. This plan was long followed by the owners of the Bethanga mines in Victoria. Their regulus contained 40 to 60 per cent. of copper, and 6 to 14 oz. of gold and 15 to 34 oz. of silver per ton. The results were not satisfactory ; but much better returns were got by reducing the stuff to coarse copper, containing 98 per cent. of copper and 9 to 12 oz. of gold per ton.

Where cost of transport and other difficulties render this plan inconvenient, recourse must be had to one of the many "processes" now to be briefly described.

Claudet's process.—This process is carried out by Claudet and Phillips for extracting the metals from the residue of Spanish cupreous pyrites, used in the manufacture of sulphuric acid, at Widnes, near Liverpool, in the following manner. (1) The residue (burnt pyrites) is roasted at a very low temperature, with the addition of common salt : the oxidation of the metallic sulphides and the decomposition of the sodium chloride give rise to the formation of sodium sulphate and soluble copper chloride, with the chlorides of gold and silver, soluble in copper and sodium chlorides. (2) The roasted mass is washed with water, to remove the soluble chlorides, including those of the gold, silver, and copper. (3) A weak solution of potassium or zinc iodide is added, to convert the soluble silver chloride into insoluble. (4) The precipitated iodide of silver is reduced by zinc plates, with formation of soluble zinc iodide, which is utilized for precipitating the silver in subsequent operations. (5) The reduced metals are melted, producing copper and auriferous silver.

By this process, the gold is obtained as a bye-product at very small expense. But the conditions necessary for the success of the process are probably present in no gold-mining district: they embrace (1) an extensive manufacture of sulphuric acid, (2) an abundant and cheap supply of salt, (3) a large demand for sodium sulphate, and (4) a ready market for enormous quantities of iron oxide.

Henderson's process.—The Bede Metal Co. formerly* adopted the following method of separating the gold and silver from the solutions obtained in lixiviating the calcined copper-ores, according to the wet system originally introduced by W. Henderson. It depends on the fact that when sulphuretted hydrogen is passed through a copper solution containing a small proportion of silver, the latter metal is at first precipitated in much larger proportion than the former. In precipitating in this way 5 or 6 per cent. of copper from ordinary copper liquors, containing about 20 oz. of silver per ton of copper, no less than 80 per cent. of the silver is precipitated. Sulphide of copper is obtained, containing about 200 oz. of silver per ton of copper, and this is calcined and further treated for the separation of the silver, ultimately yielding a residue consisting of sulphates of lead and lime, oxide of iron, and chloride of silver, the last-named metal amounting to 8 or 9 per cent. of the total weight of residue. Henderson dilutes his solutions to 20° or 25° Tw., and adds a very weak solution of lead acetate, by which he obtains a cream-coloured precipitate containing about 53 per cent. of lead, 5 or 6 per cent. of silver, and 3 oz. of gold to each ton of precipitate.

Hollway's process.—Hollway's process for smelting the Spanish copper-pyrites is based on the utilization of the sulphur in the sulphides for conducting their combustion, and the application of the sulphurous acid produced to the manufacture of sulphuric acid, or other purposes. The first condition is that the whole of the oxygen of the air driven into a thin stratum of protosulphide of iron (FeS) is utilized for oxidation; and the second, that by the heat evolved in the rapid oxidation of sulphides, and without the use of extraneous fuel other than that employed in producing a blast,—(*a*) about half the sulphur contained in the iron-pyrites (FeS_2) is expelled in the free state; (*b*) the remainder of the sulphur, excepting that left with the regulus, is principally evolved as sulphurous acid; (*c*) though only about 20 per cent. of sulphur is oxidized, the proportion of sulphurous acid to nitrogen is 14·9, or larger

* Thomas Gibb, Esq., President of the Tyne Chemical Society, in an obliging communication to the author, dated Dec. 4, 1880, states that this process is "now discontinued on account of local circumstances. Claudet's process is now the only one used for treatment of these liquors" in England.

than that commonly obtained by copper-smelters who manufacture sulphuric acid; (*d*) volatile metallic sulphides, such as arsenic and lead sulphides, are distilled off with the sulphur; (*e*) copper, silver, gold, and nickel will be concentrated in the regulus, provided an excess of iron sulphide is always present. The quantity of coal necessary to produce the blast, calculated on the oxygen requisite for the oxidation which takes place, is 1⅓ cwt. per ton of pyrites. The process seems chiefly advantageous for copper-smelters treating rich copper-ores, and who can utilize the sulphuric acid made.

Hunt and Douglas' process.—In the process invented by Prof. Thomas Sterry Hunt and James Douglas, the copper is removed from its ores in a dissolved state, the solvent employed being an aqueous solution of neutral iron protochloride and common salt. Most oxidized compounds of copper, when digested in such a solution, are converted into a mixture of protochloride and dichloride of copper, which are dissolved, while the iron of the solvent separates in the form of insoluble hydrous peroxide of iron. When the solution of the copper chlorides is brought into contact with metallic iron, the copper is separated in a metallic crystalline state, while the iron passes into solution, reproducing the iron protochloride, which is fit for use on a fresh portion of copper-ore. The reactions between the iron protochloride and the copper oxides may be thus expressed:—

For the protoxide: $3\,Cu_2O_2 + 4\,FeCl = 2\,Fe_2O_3 + 2\,Cu_2Cl + 2\,CuCl.$
For the binoxide: $3\,Cu_2O + 2\,FeCl = Fe_2O_3 + 2\,Cu_2Cl + 2\,Cu.$
The metallic copper and protochloride react thus: $2\,CuCl + 2\,Cu = 2\,Cu_2Cl.$

The process is applicable to all ores of copper, but sulphuretted ores must first be roasted. Auriferous and argentiferous ores, chlorinated by this bath, may be subsequently treated either by dissolving the silver from the washed residues by a solution of sodium hyposulphite or chloride, or by amalgamation. The latter is preferable for ores carrying gold: such should be treated with the bath in a raw state, or after simple calcination. The process is very simple and inexpensive, is applicable to all ores of copper, requires no repeated addition of salts or acids, produces a superior copper, and needs only ¾ ton of iron for each 1 ton of copper produced.

Mears' process.—The Mears' chlorination process is a modification of the well-known Plattner's chlorination process, differing mainly in the hastening of the combination of chlorine and metal by applying a concentrated solution of chlorine under pressure. Charges of pyrites of about 1 ton each are treated in revolving, air-tight, lead-lined, iron cylinders, 100 to 200 gal. of water being present with each charge. When the chlorination is complete, the fluid mud is poured into a filter, whence the gold chloride in solution runs to a precipitating-tank, where it is thrown down by iron sulphate.

In this process, the ore has first to be de-sulphurized by roasting in a reverberatory or other furnace. The chlorine required may be generated in whatever way is best adapted to the circumstances. When the chlorination of a charge is completed, the excess of chlorine gas in the chlorinating cylinder and that absorbed by the water is withdrawn for re-use. The chlorinated mass is leached to liberate the gold chloride in solution. The gold is precipitated from the solution either (*a*) by iron sulphate, with subsequent washing with sulphuric acid and smelting with borax, or (*b*) by filtering through charcoal, subsequently drying and incinerating the mass, washing out the ashes, and smelting as before. It is said that concentrated pyrites can be treated at a cost of less than $5 (say 1*l.*) per ton in California.

Monnier's process.—Prof. Monnier's sulphatization process is used at the New Providence mine, Nevada. The ore is hand-picked and run through Cornish rollers in the proportion of 80 per cent. of ore and 20 per cent. of sulphate of soda, until it passes through screens with 576 holes per sq. in. It is then fed into one of Bruckner's revolving roasting furnaces, 40 ft. long by 5 ft. in diameter, with a fall of 6 in. for its length towards the discharge end. The hearth is at the discharge end, and thus the flames meet the slowly descending ores, whilst the furnace revolves 3 times a minute. The chemical reaction in this furnace is as follows. The oxidation of sulphur produces sulphuric acid, which combines with the soda, forming a bisulphate of soda, and when this substance approaches the vicinity of the hearth, near its final discharge from the furnace, it is decomposed, and the bisulphate gives up sulphuric acid, reacting on the sulphates and oxides that may have formed, at the same time converting into soluble sulphates silver, copper, lead, &c., iron alone remaining an oxide. The roasted ore is then placed in large tanks with water for "lixiviation" or leaching, and the liquor obtained is passed through layers of "cement copper" (pure) in other vats, in order to precipitate a portion of the sulphate of silver whilst the liquid retains a low temperature. The remaining solution is then run through an evaporating-pan, in order to regain the sulphate of soda for repetitionary use, and in this manner the process is continued until insoluble residues are obtained, which contain the gold and some silver; these are carefully ground in *arrastras*, and finally passed over electro-copper plates and through mercury wells, upon and in which the more precious metals are retained by amalgamation for subsequent retorting. The results obtained are said to be at the rate of 88 to 93 per cent. on the assay for gold, 70 per cent. for silver, and the whole of the copper. An advantage claimed for Monnier's process consists in the fact that in other processes the miners lose the silver during chlorination, and that chlorination of gold takes 48 hours on the average, whereas, by this manipulation, all the more valuable metals are collected, and this can be done in about half the time.

Paul's process.—The "electric dry amalgamating" process introduced by Almarin B. Paul is widely adopted in California. It is mainly as follows. The ore is first heated to dryness, and then reduced in the dry way by any suitable machinery to a fineness that will allow it to pass through No. 14 wire cloth. The crushed ore is next pulverized to fine flour in a barrel, and thence conveyed to an iron, wooden, or earthen cylinder, with the addition of 20 to 25 per cent. of mercury, the whole being shaken up together for about an hour. The process is said to be effective and cheap, and to entail only a small loss of mercury.

Plattner's process.—Plattner's original chlorination process has been introduced with modifications by Deetken into Grass Valley, California, and by the United Pyrites Co. into Sandhurst, Victoria. An account of the *modus operandi* of the latter has been most obligingly communicated to the author by C. W. Chapman, the Co.'s manager, which may best be reproduced in his own words.

"The operations to which concentrated pyrites is subjected are the following:—(1) Oxidation and sometimes partial chlorination by roasting in a revolving furnace; (2) impregnation of the roasted pyrites in vats; (3) leaching with cold water, and filtration of the solution; (4) precipitation of the gold by sulphate of iron; (5) smelting the auriferous residuum. The finer the concentrates, the quicker and easier will the process be performed.

"By pyrites, is here meant the sulphides and arsenides of iron, copper, zinc, and lead. The presence of galena, blende, or copper-pyrites does not interfere with chlorination; but when they are present, the roasting must be protracted, and more carefully performed. Gold alloyed with 10 to 20 per cent. of silver is more easily obtained by this process than when in a state of comparative purity. Coarse gold does not admit of chlorination. Pan-tailings allow a perfect extraction of the gold by this process. The presence of lime or magnesia makes chlorination of the roasted pyrites troublesome; the use of salt in roasting partially removes this difficulty. If lime, baryta, &c., be present, hydrogen sulphide may be used to precipitate the gold, and then the earthy metals will remain in solution.

"The roasting is the most important part of the whole process, and that on which the success of the subsequent operations depends. The sooner after concentration that the pyrites is roasted the better, so that no crusts or lumps may be formed by partial decomposition; any hard lumps must be sifted out, and subjected to some disintegrating process.

Not more than 1 per cent. of the sulphur shown by analysis should remain after roasting in an unoxidized state.

"The construction of the furnace has but little influence on the chemical results of roasting; the best construction is that where the flame of the fuel comes into direct contact with the pyrites. The chief thing is to keep the cost down, and this is obtained by revolving the furnace, and so obtaining a mechanical stirring.

"In all furnaces, at the beginning of roasting at a low temperature, the sulphur of the pyrites is set free, combining with the oxygen of the air to form volatile sulphurous acid gas, which is well known by its odour. The metals, by losing a part of their sulphur, are converted into oxides and sulphates. Sulphate of iron is the precipitant of gold from the chloride; its presence is therefore objectionable, and it is necessary to increase the heat by degrees in order to decompose the sulphates, and to form oxides. Similar is the behaviour of arsenical pyrites; arsenious acid and sulphurous acid escape under the influence of heat and oxygen, whilst oxides, arseniates, and sulphates remain, and are further decomposed by increased heat. At the same time, all metallic iron derived from the abrasion of the stamps must be converted into an oxide.

"After the sulphur and arsenic have been driven off, provided salt has not been used, the gold remains free, and may be observed upon vanning a sample. When salt is used, according to Plattner, $AuCl_3$ is formed below red-heat; at 200° C. (392° F.), it changes to AuCl, and at a red-heat it is converted into metallic gold.

"Assertions are made from time to time that gold is lost in roasting; but proofs are wanting: experiments only show that gold in a very fine state of division is carried to an inappreciable amount into the flue by the draught.

"The furnaces used formerly by the United Pyrites Co. were reverberatory, 45 ft. long, 5 ft. 6 in. wide, with a sloping hearth, and port-holes for stirring the pyrites during the roasting process. These answered the purpose very well; but desiring a more economical roasting, a furnace of boiler-plate has been built, in two sections, each lined with brick, and revolving independently. The total length is 90 ft. One section is 3 ft. in diameter, and the other 4 ft., with a drop from one to the other.

"The time the pyrites occupies in the furnace depends on its composition, and this may be nearly enough ascertained by watching the behaviour of a sample roasting in the muffle furnace. The faster or slower the furnaces are revolved, the faster or slower will the pyrites be passed through. The roasted pyrites runs into a truck, and is then wheeled to the cooling-floor, where it is eventually moistened, and then trucked to the chlorination-vats.

"The roasted pyrites must be moistened, so as to lie in an open working condition in the vat, and because the chlorine gas will act more energetically upon the material in a moist condition than in the dry state. The moistening may be conveniently done with a hose, turning the mass over several times, so that no portion may remain dry; and the proper amount of moisture may be ascertained by compressing a handful to form a lump, which should retain its shape until handled. If too dry, more water may be added; and if too wet, more dry material.

"The vats are made of wood, to hold 1 to 5 tons, and are shallow in proportion to their diameter; they are coated inside with a mixture of pitch and tar, to prevent absorption of the gold solution: above the bottom is an empty space about 1 in. high, covered with a false bottom of perforated boards. The boards are supported by short pieces of wood, leaving sufficient space for the chlorine gas to pass. Over the false bottom a filter is made in the following manner:—1st layer, 1- to 1½-in. quartz gravel; 2nd layer, ½-in.; 3rd, ¼-in.; then coarse sand; and finally fine sand; making a filter about 5 in. thick; this filter remains always in the vat, unless repairs have to be effected. Under the false bottom are three holes, two by which chlorine may be introduced, and the third for the discharge of the lixivium. After a charge has been removed, the filter retains a great deal of moisture, which is drawn up into the new charge; therefore some dry material is placed first upon it, to absorb this moisture.

"The moistened pyrites is sifted into the vat, that it may be evenly and loosely distributed, and to free it from any stones or crusts formed during the roasting. This is done by pushing the sieve to and fro upon two pieces of quartering over the vat.

"There are three 10-ft. vats, one 8-ft. and one 6-ft., all 3 ft. high. The covers are made gas-tight and fit into a step, which is luted round with linseed-meal when the gas rises to the top. They are raised and lowered by a block and tackle.

"The chlorine gas is generated in an earthenware vessel of about 20 gal. capacity, like a large jar, only that the top, besides the central large opening, has two smaller ones, one containing a pipe, bent somewhat like the letter S, with the outer end widened for a funnel, through which the sulphuric acid is introduced; the other conveys the chlorine through a washing apparatus to the vat.

"The gas-generator stands on bricks in a wooden tub containing water heated by steam, and this tub stands on a truck so that it may be moved for cleaning the generator, or connecting with any one of the row of vats.

"When a vat has been charged within 6 in. of its top, two generators are put into position, and connected with the vat. Into each generator, for a 10-ft. vat, are put 16 lb. of manganese, 17 to 20 lb. of salt, 35 lb. of sulphuric acid, and 20 lb. of water; all but the sulphuric acid are introduced through the central opening, and lastly the sulphuric acid is run through the leaden pipe referred to before. The chlorine gas is not allowed to pass directly to the vat, but through a washing apparatus, made by half filling a wash-basin with warm water, and conveying the gas from the generator into it by a leaden pipe, the mouth of which is turned upwards, and placed ½ in. under the water. Another pipe, turned the same way, but with its mouth above water, leads into the vat; over the mouths of both these pipes, and reaching down into the water, is a Winchester quart bottle with the bottom cut off. By this means the gas is washed free from hydrochloric acid. Twice a day is often enough to change the water, which is used warm because warm water absorbs less chlorine than cold.

"The object of this apparatus is not only to wash the chlorine, but to afford an indicator of the progress in the generator. The bottle must show a greenish gas, and the bubbling should be lively; should this not be the case, the remedy is more sulphuric acid, until the last of the allowance is used up; afterwards steam is turned on in the tub to heat the contents of the generator, and from time to time the contents are stirred through the large opening to prevent caking. The vat, after the pyrites has been sifted in as described, is left uncovered until the gas reaches the top of the charge, which should be within 3 to 6 hours; progress is ascertained by the odour of samples, taken by hand, from beneath the surface. When the gas has been within an inch or so of the top, the cover is brought down and luted on with linseed-meal; no escape of gas is allowable, as the respiration of chlorine is not only injurious but very disagreeable, so the cover must be quite impervious. A small hole closed by a cork is opened from time to time, to ascertain if the gas is up to the top; this is done by presenting a glass rod dipped in ammonia at the hole, when, if chlorine is present, copious white fumes are given off. The chlorine is now permitted to operate upon the gold for 12 to 16 hours.

"After the allotted time, the cover is unluted and raised by block and tackle. A spout affixed to a piece of quartering is placed on the vat, and the hose is turned into it. When the vat is full, and no air-bubbles appear, the outlet leaden tube is opened, and the water of lixiviation is allowed to run from under the false bottom into 30-gal. earthenware pans, care being taken that the hose delivers a quantity of water sufficient to keep the vat full, so that as much may be replaced as runs out below. The flow is allowed into the earthenware precipitating-pans until about 90 gal. has run after the last reaction was obtained in a test-tube with sulphate of iron; the supply through the hose is then stopped, and the vat is allowed to drain until the time comes for throwing out the tailings.

"The precipitating-pans are of glazed earthenware, made at a local pottery; they are twice the height of their diameter, and have a capacity of 30 gal.; 5 stand on a turntable, on a truck, and their tops are about 6 in. below the bottoms of the vats. After the addition of sulphate of iron, they remain undisturbed all night; in the morning, the clear liquid is syphoned into a drain, and runs away, and the auriferous deposit is concentrated into pans standing at a lower level.

"The sulphate of iron is made from scrap iron and dilute sulphuric acid in a series of earthenware pans; some is made every day, and the clear solution from that made the week before comes into use.

"The quantity of sulphate of iron used is always in excess of that supposed to be required, and the test of sufficiency is made by filtering a small quantity of the liquid from the precipitating-vat, adding some sulphate of iron solution, and noting whether the mixture darkens in colour; if it does, more sulphate of iron must be added. When all the auriferous precipitate has been collected into one pan, a fine spray being used finally within the upper series of pans, this is allowed to settle; the supernatant liquid is then syphoned off, and the precipitate is thrown on filter-papers within large funnels, and filtered; the precipitate is well washed, dried in a hot-air oven, and finally smelted in Hessian crucibles, a little nitre, carbonate of soda, borax, and salt being used as fluxes.

"The tailings from the vats are thrown out with a shovel into a trough, and sluiced out of the building. This trough is laid down with coir (coco-nut fibre) matting to arrest any stray particles of coarse gold which have resisted chlorination; the gold obtained from this source, though small in amount per ton, reaches an appreciable quantity per annum.

"Remarks.—Blende is troublesome, on account of the difficulty there is in driving off the sulphur. Antimony sulphide is still more so, because it agglomerates, and fuses so readily. The presence of 6 per cent. of galena does not prevent the gold being successfully obtained; a higher percentage has not been experienced.

"American and German writers give 95 per cent. of the assay as the average yield from successful chlorination; but percentages are delusive, as the following will illustrate:—

	oz.	dwt.				oz.	dwt.	gr.			oz.	dwt.	gr.
Assay	10	0	per ton	..	95 per cent=	9	10	0;	loss 5 per cent=		0	10	0
Assay	0	10	per ton	..	95 per cent=	0	9	12;	loss 5 per cent=		0	0	12

"In dealing with percentages, the work has been done equally well in both instances, which is absurd, as the loss in the first is equal to the total amount as shown by assay in the second.

"The condition of the pyrites being the same, the loss is practically constant, or about 2 dwt. per ton, no matter whether assaying 10 dwt. or 20 oz. per ton. Any increase in the loss is due to faulty condition, as coarse crushing, or lumps and accretions caused by partial decomposition having set in.

"The United Pyrites Co.'s chlorination works have been established for about 4 years, and have been in constant operation during that time; about 50 tons per week is the capacity. For 5 years previous to this, the same company operated amalgamation works successfully.

"The progress of the work is—2 vats are charged and 2 emptied every day.

"The process, from the time the pyrites goes into the furnace to the time when the gold is ready for sale, occupies 10 days on the average. Over 8 tons is the average per diem through a month's or 12 months' run.

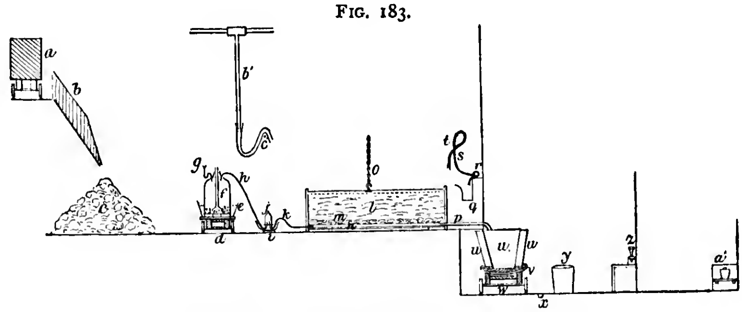
PRICES OF MATERIALS WITH CARRIAGE ADDED.

	£	s.	d.	
Manganese	6	0	0	per ton in the lump.
Salt	3	10	0	from neighbouring lakes.
Sulphuric acid	12	0	0	per ton (1·720 sp. gr.).

Labour, 35*s.* to 55*s.* per week.
Carpenters, masons, and bricklayers, 60*s.* per week.
Wages and supervision amount to about 20*s.* per ton."

The apparatus is shown in Figs. 183 and 184. The reference letters indicate as follows. Fig. 183: *a*, truck conveying roasted pyrites outside the building; *b*, shoot to convey same inside; *c*, heap of roasted

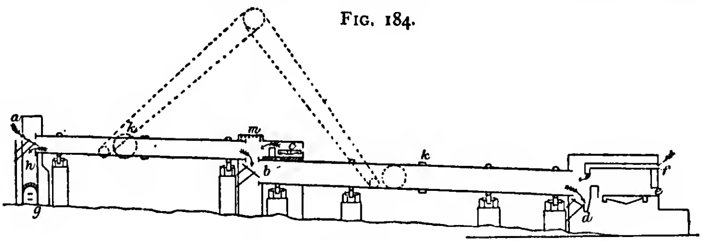
FIG. 183.



CHLORINATION AS CONDUCTED AT SANDHURST.

ore; *d*, truck for generator; *e*, tub in which generator stands; *f*, generator with stirrer; *g*, sulphuric-acid pipe; *h*, chlorine pipe; *i*, wash-basin; *j*, Winchester quart with bottom off; *k*, chlorine pipe; *l*, vat filled to within 6 in. of top; *m*, filter bed; *n*, space under the false bottom; *o*, rope or chain for lifting the lid; *p*, pipe for conveying lixivium into precipitating-pans; *q*, sluice-trough; *r*, water main; *s*, indiarubber hose; *t*, peg to hang up hose; *u*, earthenware precipitating-pans; *v*, turntable; *w*, truck for pans; *x*, drain; *y*, concentrating-pan; *z*, filter; *a'*, drying-oven and muffle; *b'*, steam-pipe; *c'*, hose. Fig. 184: *a*, where the pyrites is fed in by a boy; *b*, drop on cast plate from upper to lower furnace; *c*, supplementary fire for starting the upper furnace; *d*, where the roasted

FIG. 184.



CHLORINATION AS CONDUCTED AT SANDHURST.

pyrites runs into a truck; *e*, fire-place; *f*, air-flue; *g*, door for clearing the dust away; *h*, flue leading to chimney; *k*, cog-wheels to take driving-gear; *m*, wrought-iron hood over the junction.

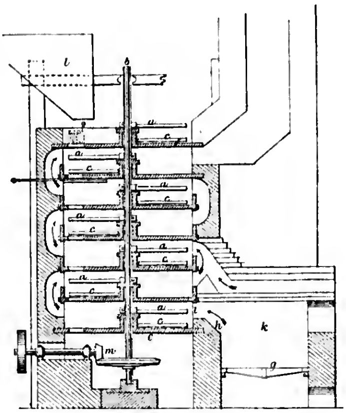
Washoe process.—The Comstock ores are divided into first, second, and third classes, according to their treatment. The first class forms but a small proportion. The ore of this class is crushed dry, roasted with salt (a modification of Plattner's chlorination), and amalgamated. The ores of the second and third classes are subjected to the "Washoe process" proper, which consists simply in reduction by wet crushing, and subsequent pan-amalgamation, in the apparatus fully described in the preceding chapter.

IRON ORES.—Iron has no effect upon the amalgamating qualities of mercury under ordinary conditions; but mercury containing about 1 per cent. of sodium-amalgam will decompose iron salts, and produce what is termed "iron-amalgam." Hence the use of too much sodium may defeat its own object by causing the mercury to take up (though only temporarily) the base metals.

In all gold-mining districts, immense quantities of iron-pyrites are produced. It has often been suggested that this pyrites should be treated in the same way as similar ores are dealt with in England for the production of alum, sulphur, and sulphate of iron. Stacks could be made of alternating thin layers of pyrites, aluminous shales, and fuel, and thus the gold would be left in the residue in a condition suitable for amalgamation. By simple exposure to the atmosphere and weather for a prolonged period, the pyrites undergoes considerable oxidation, with consequent liberation of the gold. Heaps of pyrites thus exposed are often sold to Chinamen, who make a good profit by their manipulation. But oxidation by natural means is necessarily a very slow operation, and several forms of furnace have been introduced for hastening it.

In Denny's self-acting drop-furnace (Fig. 185), the pyrites is delivered into a hopper on the top plate of the furnace. This plate has a self-acting grate, which, acting automatically, admits the necessary quantity of pyrites on to the second floor. The arm *a* revolves with the shaft *b*, and the loose rake *c* sweeps the pyrites round the iron floor, thus presenting fresh particles of the matter under treatment to the passing oxygen. The top floor is for drying only. The next floor retains a charge of about 4 cwt. for 20 minutes, during which time it is continually stirred by the revolving arm, thus preventing caking, and ensuring free access of the oxygen to every particle of pyrites. At the end of the time named, the boy in attendance opens the hole in the floor by shifting a slide *d*, when the revolving arm sweeps the whole of the charge round, dropping it on the next floor. The operation of opening the slides and allowing the charge to drop is continued from floor to floor until it reaches the bottom thoroughly and completely oxidized. The furnace is built on a brick foundation, which supports the lower plate *e*. The next plate is 15 in. apart, and the others an equal distance. The shaft *b* passes through the centre of the plates, and is fitted with wrought-iron arms, which have loose rakes attached to them for sweeping the floors. The fuel is burnt on the bars *g*, and the products of combustion pass over the bridge *h* into the first floor, thence into the second, as indicated by arrows, and on the top. The free oxygen enters the hot-air furnace *j*, and passes into the third and fourth floor, combining with the base metals it comes into contact with. The carbon of the wood, having entered into union with its full amount of oxygen in the furnace, cannot take up any more. It therefore merely passes through the flues, heating the pyrites it comes into contact with, thus preparing it for entering into union with the free oxygen. The vertical shaft is driven by a pair of bevel-wheels *m*, and causes the whole of the arms to revolve. *k* is the fireplace, and *l*, the hopper.

Fig. 185.



Denny's Drop-furnace.

Lead ores.—Various ores of lead, such as galena (sulphide), antimonial lead, sulphate, carbonate, arseniate, and phosphate of lead, are often mèt with in auriferous veins. The metallic lead derived from them has a highly detrimental effect upon the amalgamation process, causing a loss of gold-amalgam and mercury, through the lead-amalgam rising to the surface of the mercury as a frothy scum, carrying with it any gold-amalgam that may be present, and, by forming a coating over the mercury, preventing it taking up any gold that may pass over its surface. The lead-amalgam, when thus brought to the top, is easily broken up and carried away in a fine state of division by a stream of water passing over it. The whole of the lead-amalgam does not rise at once, and cannot be completely removed by simple skimming; but the more the mercury holding it is agitated, the quicker it rises. Metallic lead is sure to be reduced from any of the ores by the operation of roasting, and losses will therefore be increased in that way.

Austrian process.—At Lend, in Austria, a fusion process is used for the very poor ores of Zell, Rauris, and Boeckstein (see pp. 708–9). These ores contain arsenical pyrites, the sulphides of antimony, copper, iron, lead, and zinc, and a very small proportion of gold and silver, alloying 15·33 gold and 84·67 silver. The operations carried out are as follows:—(1) Fusion for raw matte, (2) roasting of raw matte in stalls, (3) fusion without lead for a more concentrated matte, (4) roasting 2nd matte in stalls, (5) fusion with lead, (6) cupellation of rich lead.

The 1st fusion is in a furnace 24 ft. high, 3 ft. diam. of hearth, 4·5 ft. diam. of boshes, 2 ft. diam. of throat; 2 tuyères; $\frac{1}{8}$ to $\frac{1}{2}$ in. of mercury; worked with a black throat.

The 1st matte averages in composition: iron, 55·1; copper, 4·3; zinc, 3·7; lead, 2·1; nickel, cobalt, arsenic, and antimony, 4·5; sulphur, 27·9; = 97·6. It contains 30 to 40 oz. troy of auriferous silver per ton.

The 1st matte is roasted 3 times in stalls containing 28 tons, and then worked with most extreme care in a furnace with a larger hearth and under much less pressure.

The 2nd matte is roasted as before, but with different conditions; when the hearth is full of melted matte, it is tapped, and the products run into a basin, where they are well stirred with poles. The matte is then partially taken off, the lead remaining until 600 to 700 lb. have collected. For a perfect extraction of the silver, it is necessary to charge 120 to 130 lb. of lead for each 1 lb. of silver and gold, which extracts 75 per cent. of these metals in one operation. The extraction of 75 per cent. of auriferous silver means that more than 90 per cent. of the gold and 73 per cent. of the silver has been obtained. A second operation removes so much more that, including amalgamation, where the loss is very great, more than 90 per cent. of the silver and 96 per cent. of the gold is obtained. This second operation takes place only when the matte is worked for copper. At other times, the gold and silver are obtained by charging the matte back in the first operation. If the 3rd matte is rich enough, it is fused with lead a second time; if it contains 35 per cent. or more of copper, it is worked for that; if under, it is roasted, and returned as a flux to the first fusion for raw matte.

Cupellation is performed in a German furnace of peculiar construction in a special way. Raymond recommends this process for the Colorado ores which are of a similar character.

Richmond process.—The ore from the Richmond mine, Nevada, is put into a blast furnace, and the lead, which is present chiefly in the form of carbonate, runs out, carrying the silver and gold. This alloy is afterwards treated by a refining process, based on the Pattison process, but worked by steam, after the system of Luce fils et Rogan of Marseilles, which separates it into soft lead free from precious metals, and a richer portion containing all the precious metals; the latter is cupelled in the usual way till all the lead is driven off, and an alloy of silver and gold is left in the cupel, to be run off into bars ("doré" bars, so-called), and sent to market as gold and silver alloys (see Silver).

SILVER.—All native gold is alloyed with silver, the latter often forming by far the greater proportion of the alloy. At Freiberg, the following simple plan is adopted for their separation. The alloy is collected in a granular form by allowing the molten metal to drop into water. The silver is then dissolved out by heating with double its weight of sulphuric acid in a cast-iron vessel in a reverberatory furnace. The gold remains undissolved, and sinks to the bottom. When first collected, it is still combined with much silver. It is washed with hot water, and again heated with sulphuric acid, until purified from silver and acid.

The gold and silver alloy obtained from the Richmond ores (see Lead) is granulated and thrown into a cast-iron vessel containing boiling sulphuric acid, which attacks the silver (when the gold contents do not exceed $\frac{1}{5}$ or $\frac{1}{4}$ of the silver), leaving the gold in a porous mass at the bottom of the vessel. The gold is collected, squeezed under a hydraulic press to remove the acid, melted, and refined. The silver solution (sulphate) is conveyed to a large leaden tank, in which are suspended copper plates; by them the silver is thrown down, and is subsequently collected, squeezed, melted, and refined. The copper solution is then evaporated, and the blue copperas is collected in the usual way, to be sold to silver-mills, where it finds a use in the amalgamating-pans.

TELLURIUM ORES.—The ores produced by the mines of Nagyág and Offenbánya, in Hungary, and by some others (see p. 844), are remarkable as containing a comparatively large proportion of tellurium, which, although it has hitherto been of no commercial importance, has latterly been in some demand on account of a new application for the construction of thermo-electric batteries. The following experiments have been undertaken to discover a cheaper method of production than those heretofore in use.

The ore, as delivered for smelting, was found to be of the following average composition: quartz, 30 to 40 per cent.; carbonate of lime, 10 to 20 per cent.; carbonate and sulphide of manganese, 15 to 20 per cent.; alumina, 5 to 8 per cent.; galena, 5 to 8 per cent.; copper-pyrites, 1 to 2½ per cent.; blende, 1 to 4 per cent.; and small quantities of cobalt, nickel, antimony, arsenic, tellurium, gold, and silver.

When such a mixture of minerals is roasted, portions of the tellurium and gold are volatilized, and may be recovered in properly-constructed condensing-chambers. The manganese compounds are converted into manganic oxide, while the greater part of the gold is reduced, so that about 50 per cent. of the total amount may be saved by amalgamation. By subsequent treatment of the roasted ore with weak hydrochloric acid, which can be done in wooden vats lined with lead, chlorine is generated in considerable quantity, through the action of the manganic oxide, and the whole of the valuable metals present, with the exception of silver, which remains in the insoluble portion, are converted into soluble chlorides. Any excess of chlorine produced in this operation is economized by condensation in water, which gives a liquor that can be used for redissolving the crude tellurium. The solution of chlorides obtained by this treatment is next cleared from lime and lead, which are precipitated as sulphates, by the addition of sulphuric acid. The separation of these sulphates is effected by subsidence and decantation, as filtration is found to present considerable difficulties.

Gold is next precipitated from the clear solution by the addition of a solution of sulphate of iron; and after filtration, tellurium, by the action of metallic zinc, which produces a black, muddy precipitate. This may, after washing with hydrochloric acid and rapid drying, be converted into crude tellurium by fusion, with any flux, in a porcelain crucible; but the product so obtained invariably contains lead, copper, nickel, and antimony, and it is therefore preferable to redissolve the first telluriferous precipitate in chlorine-water, and subject the solution for a considerable time to the action of sulphuric acid, whereby tellurium in a high state of purity can be obtained.

The original residue of the chlorination treatment contains, in addition to silver as chloride, some gold in a soluble state. By the addition of sulphate of iron to these residues when in a moist condition, the gold may be reduced, and the substance is then fit for treatment by amalgamation; but fusion with lead, when it can be done, is generally preferable.

The following results were obtained in an experiment conducted according to the above principle: 14·5 lb. of tellurium ore, containing 14 dwt. of gold and 13·9 dwt. of silver, were roasted for 1½ hour in a muffle-furnace. The loss of weight was equal to 7·2 per cent., and 0·35 per cent. of gold and 3·8 per cent. of silver were computed as lost by volatilization. The roasted ore weighed 14·3 lb., of which quantity 13·2 lb. were taken for subsequent treatment by chlorine. This was effected by mixing it with 10·4 pints of water, 6·8 pints of crude hydrochloric acid (25° B.), and 10·6 oz. of concentrated sulphuric acid. The addition of the acid was attended with effervescence, owing to the rapid evolution of carbonic acid and chlorine.

After 24 hours, the solution was diluted by the addition of 6·8 pints of water; the whole contents of the dissolving vat were stirred well together and allowed to settle for two hours, when the clear liquor was drawn off. This operation was repeated three times, giving a total quantity of 2 gal. of liquor, which was then treated with a solution of green vitriol (3·5 pints of 25° B.) in order to separate the gold. This was completely effected in 24 hours, and the resulting gold, after being washed, dried, and cupelled with lead, weighed 10·5 dwt. or 82·2 per cent. of the total contents of the ore treated—an amount that might have been increased to 90 per cent. if the washing of the residue had been more completely carried out.

The liquor remaining after the separation of the gold was next treated with 4·4 lb. of commercial zinc. The black mud precipitated, after standing 24 hours, when washed, dried, and melted, yielded 19·3 dwt. of crude tellurium, or about 0·43 per cent. of the weight of the ore operated upon. The consumption of zinc was about 3 per cent. of the weight of the ore. The argentiferous residues were found to contain 2·5 dwt. of gold and 10·9 dwt. of silver. The final result therefore, gave about 2 per cent. of gold in excess of that indicated by assay, while the loss of silver was about 8·9 per cent. These differences, especially that of the gold, may be ascribed partly to the difficulty of sampling, owing to the unequal distribution of very rich minerals in the mass of earthy substances forming the ore, and partly to the irregular loss by volatilization of the precious metals with the tellurium in the assaying processes, which is always observed with these minerals. This method is likely to be of considerable value to the Nagyág and Offenbánya mines, in the event of a demand for tellurium arising on a large scale.

ZINC.—If gold is exposed at a dull-red heat to the vapour of zinc, a brittle alloy is formed, the zinc being taken up by the gold in the same manner as arsenic. This alloy is easily amalgamated by mercury, but of course reduces the standard value of the gold.

Auriferous ores containing zinc are generally also plumbiferous, and are treated as described under Lead.

Retorting Amalgam.

Except where the gold is collected as a salt or in a pure metallic state, the final operation is to subject the mercurial amalgam to the influence of heat, in order to disengage the mercury for further use, and leave the gold in a separate state.

The heating of the amalgam is performed in retorts, built into fire-brick furnaces, care being taken to construct the fireplaces so as to allow the flames to have full play upon the retorts. The latter are of cast iron, cylindrical in form, to permit their being turned round should one side become burnt. The usual size at large works is 5 ft. long, the inside cylindrical portion being 3 ft. long by 1 ft. in diameter, and made of $1\frac{1}{2}$-in. cast iron. The neck gradually contracts to $2\frac{1}{2}$ in. diameter for a length of 2 ft., the end of the neck being furnished with a flange, to which the condensing-pipe is bolted. The condensing-pipe bends downwards, and passes through a body of water contained in a vessel constructed of boiler-iron, the water-supply and escape being continuous, and thus ensuring constant coolness, so as to effect the condensation of the volatilized mercury. The amalgam to be retorted is first squeezed through chamois-leather to express the superfluous mercury which is capable of separation in this way, and is then placed in the retorts in cast-iron trays.

APPENDIX TO CHAPTER I.

ADDITIONAL NOTES ON CHILI (pp. 231–5).

The following transcript of a letter addressed by Alexander Bertrand, Civil Engineer of Mines, to Francisco Vidal y Gormaz, and kindly forwarded by the latter gentleman to the author in response to a request for information on gold in Chili, arrived from the translator's hands too late for incorporation in the text.

"SANTIAGO, CHILI, 10 *Dec.* 1881.

"I have the pleasure of replying to your esteemed letter of the 1st inst., in which you ask for information concerning the gold-washing of Niblinto, of which I have been manager throughout its working. In view of the object of your inquiries, I shall be as brief as I can without omitting the notice of anything of importance. I shall also annex to some technical terms the corresponding words in English, in order to facilitate the translation to the person interested.

"The gold-washings (called in California "placers") of Niblinto are situated in 36° 40′ S., some 10 to 12 leagues to the east of the city of Chillan; the auriferous deposits lie between various ravines or gullies, which join a little below the said gold-washings, forming one of the deep valleys which deliver their waters into the river Cato, an affluent in its turn of the larger river Truble. The rivers and ravines mentioned determine the form of certain hills and ridges, which come down from the Andes. This region was formerly a dense forest, but now the greater part of it is cleared. The geological character of the locality is, in its base, granitic, and especially felspathic. In the bottoms of some ravines may be seen the hard granite, granitic conglomerate, and homogeneous felspathic rock; but in the rocky hills these rocks have been decomposed to such a degree, that the bed-rock of the 'gold-washing' is in general a kind of clay, spotted with grains of mica, but which still retains the structure of its original rock, from which it differs only in its softness. In the rocky hill itself, called 'of the Nalcas,' the lower parts of which contain the auriferous deposits, the homogeneous felspathic rock contains lodes and strings (or veins) carrying gold, and in the old workings are found china-clays forming the side-walls of the lode. These lodes, the probable source of the auriferous deposits of the present gold-washings, though narrow, have been productive, and were abandoned by their primitive workers, through having arrived at a depth at which the water flooded the work. Returning to the gold-washing, it is to be noted that the surface of the bed-rock is irregular, and that this irregularity, due to its origin, has been increased by the erosive action which produced the deposit. This, which differs much from the auriferous gravels, is rather a conglomerate, kept together by a clayey cement, which contains many pebbles of an irregular and oblong form. These are of granite and porphyry, of no great size, and their edges and corners indicate no long exposure to the action of running water. This deposit does not extend uniformly over all the bed-rock, but lies in 'leads' parallel to the ravines, and also in irregular patches. As Domeyke mentions in his account of his travels in 1848, 'neither pebbles of quartz, nor of iron-ore, nor of other mineral substances which are usually found in auriferous ground (meaning gold-washing ground) are met with in this locality, but only round or reniform pieces of jasper and chalcedony, which seem to result from the destruction of the secondary porphyries, which throughout the Andes overlie the granite.' This stratum, or *manto* as the miners call it, is the most auriferous part of the deposit, and the only one that pays to work. It contains the gold in the forms of leaves and spongy grains ("curly" gold they call it), frequently with adherent pieces of quartz, having come, doubtless, from the lodes and veins. The value of the produce in gold of this auriferous bed or *manto* has in some parts reached $10 and even $20 (of say 4*s.* each) per cub. mètre. In others, it has been $3 to 6, and in the poorest part, which remains unwrought, falls to $2 or even to $½, or less. There are also in many places *mantos* barren of gold. These are called there *manturrones*, and they generally contain less hard stones than the productive bed.

"The thickness of the *manto* or productive bed varies like its produce. Generally not exceeding 1½ mètre, it in some places reaches 3 or 4 mètres, but does not retain the latter thickness for any considerable distance. Above the *manto* occur various strata of clays and china-clays, called there *masacotes*, which in some parts alternate and mingle with the *mantos* and *manturrones;* and over the ground thus formed extend various uniform alluvial strata of clayey earth covered superficially by a stratum of vegetable soil, quite without calcareous matter, known by the name of *trumao*. In places these clay strata give a little very minute gold (specks), reaching $0·40 per cub. mètre, but cannot in general be considered productive. In the lands bordering on the auriferous deposits, the bed-rock is found immediately beneath the vegetable soil.

"This gold-washing was discovered, I believe, in 1845, and was in 1848, when Domeyke visited the mountains of Chillan, in its greatest activity, as the village of 'the mines' counted then 3000 to 4000 inhabitants. Domeyke thus describes the process then employed by the miners of the locality. 'First a cutting is made, near the lower end or side of the auriferous deposit, vertically from the surface down to the bed-rock itself; from this point a trench is cut, of sufficient width and fall to carry off the muddy water, to the nearest point at which the ground may be low enough to afford it a free exit. Then water is conducted from the nearest stream that comes from the high lands, so as to fall, as if from a spout, over the inner and deeper end of this cutting. The ground is thus broken up and disintegrated, and the clay and other earthy matters are washed away by the current, this effect being assisted by the use of rakes with one broad but pointed tooth, called *almocáfres*. When a convenient quantity of ground has been thus broken up and washed, the cutting is 'cleaned up,' that is, the stones which lie heaped in the end of the cutting, under the stream of water, are collected by hand, and built into rude walls on either side of the excavation, so as to occupy the least space possible. If necessary, the stream of water is partially cut off while this is going on. The remaining deposit in the bottom of the cutting will consist of small gravel, coarse sand (some of which is ferruginous), and gold. The gravel and coarse non-ferruginous sand are separated from the gold by washing by hand in wooden pans (*bateas*), and the ferruginous sand (black) is taken out with a magnet. The gold alone then remains. The operation of washing and breaking up ground is then resumed until another cleaning-up day comes. When it becomes necessary, the stream of water is shifted to the right or left, and carried forward so as to commence the attack on a fresh strip of auriferous ground, and so on until the whole auriferous deposit be worked out.'

"The extraction of the gold from the mineral of the lodes or veins used to be accomplished by a very primitive method of amalgamation: grinding the auriferous rock with mercury in certain stone mills, called *marayes*. As you know, the process I have described has been the only one used at Niblinto for many years, and there is no doubt that it is very rational, when applied to a deposit so irregular. Less than 10 years ago a company was formed to work this auriferous ground by the hydraulic method; unfortunately the preliminary examinations were somewhat incomplete, and, relying on an inspection of the part already worked, the extent and richness of the remaining auriferous ground was exaggerated. The hydraulic machinery, with its pipes, giants, and nozzles, was erected, a long canal was excavated, to bring the water to the height required to obtain a sufficient pressure or 'head,' and lastly also there was excavated and constructed a sluice-box with block-pavement. But the first year's working of all this revealed that the richest part of the deposit had been already worked out, with the exception of some patches; while the examinations made by myself during my administration very much narrowed the limits of the auriferous ground. On the other hand, the discontinuity of the *manto* renders the hydraulic method very expensive, owing to the great length of pipes required. The company has had to abandon, for the present at least, its enterprise, having sunk in it a sum of money by no means inconsiderable.

"I have paid a visit to the gold-washing at Catapilco, not far from the coast, to the North and near Valparaiso, and am able to add some particulars concerning that locality. The bed-rock is a hard granite; the lead of *manto* crosses the upper part of several ravines, and is composed of a true coarse gravel, some of the stones weighing several hundred lb.; the cement is a hard clay; it contains gold in all its thickness, but the largest grains are found close to the bed-rock. I understand that the width of the lead is about 60 mètres. I am not well informed as to the produce of this *manto*, but it is not probably a high one, nor is the ground suitable for hydraulic working, which has not been continued here, and the establishment of which was even more costly than at Niblinto. It is to be noticed also that the supply of water is more scanty at Catapilco than at Niblinto. Hoping that these notes, though put together in haste, may be of some utility, and regretting that I am not in a position to supply similar information concerning other stream-works in Chili.

"I am, Sir, yours very faithfully,

"ALEXANDER BERTRAND,
"*Civil Engineer of Mines.*"

ADDITIONAL NOTES ON PERU (pp. 248-53).

The following list of gold-producing localities, from Paz Soldan's Geographical Dictionary of Peru, arrived from the translator too late for incorporation in the text. The abbreviations are as follows:—Dpt. for department, prov. for province, dist. for district, alt. for elevation in English ft. The leagues mentioned are of 20,000 Spanish ft. = 5572 mètres. The numerals which follow the word "produce" mean the number of parts of metal contained in 12,000 parts of mineral.

Accocunca, dpt. Puno, prov. Sandia, dist. Patambuco. The sands of this neighbourhood are worked for gold by inhabitants.

Aguados, gold-mine in Cerro of Tiquimbre to the E. of Alpacay, dpt. Arequipa, prov. Condesuyos.

Alcayan, 3 mines of gold, copper and lead, 2 S.E. and the other N. of Uco, dpt. Ancachs, prov. Huari, dist. Uco.

Alcotoral, mine of gold and silver, to the N.E. of village of Huari, dpt. Ancachs, prov. and dist. Huari; produce, 37 to 75.

Alcumbrera, rocky mountain containing gold-mineral, near Ocongate, dpt. Cuzco, prov. Quispicanchi.

Algallama, mine of gold, silver and lead, dpt. Libertad, prov. Huamachuco, dist. Mollepata.

Alta Gracia, gold-washing near the mineral-ground of Chaluma, and the place called Versailles. Sands so rich that from 15 lb. there used to be taken 45 oz. of gold ($= \frac{45}{240}$), dpt. Puno, prov. Caravaya. Want of means and the very bad roads prevent the extraction of the riches of Caravaya; (reported) produce, 2250.

Ananca, stony mountains in the Andes, about 3 leagues from which are many mines of gold-ore, now fallen in, that were worked before the conquest (say A.D. 1530); prov. Asángaro, to the E. of village of that name.

Antonio, San, (1) gold-mine, dpt. Libertad, prov. Pataz, dist. Soledad, to the E. of this village; produce, 1.

Antonio, San, (2) stream-gold, dpt. Puno, prov. Sandia, dist. Poto.

Aporuma, ancient mineral-ground of gold, near the river Inambari, dpt. Puno, prov. Caravaya.

Arguelles (probably Argüelles), gold mine in the mountain of Tiquimbre, dpt. Arequipa, prov. Condesuyos, dist. Alpacay, to the E. of this village.

Arirahua, cerro with mineral of gold and silver, dpt. Arequipa, prov. Condesuyos, dist. Salamanca; yielded many fortunes.

Arzobispo, gold-mine in the rocky hill of Arapa, dpt. Ancachs, prov. Huaras, dist. Recuay.

Asenta, gold-washing, dpt. Puno, prov. Sandia, dist. Phara.

Asiento, gold-washing, dpt. Puno, prov. Caravaya, dist. Ollachea.

Asuncion, dpt. and prov. Cajamarca; in its neighbourhood are mines of gold; it is 8 leagues from Cajamarca.

Aviso, mine of gold, silver and lead, dpt. Libertad, prov. Huamachuco, dist. Mollepata.

Banqueria, gold-mine, dpt. Libertad, prov. Pataz, dist. Chilia; produce, $\frac{1}{8} = \frac{1}{96000}$.

Bàrbara, Santa, gold-mine in the rocky hill of Tancay, dpt. Ancachs, prov. Huaylas, dist. Caras.

Bronce, El, gold-mine, dpt. Libertad, prov. and dist. Pataz, lies N. of this village; produce, $\frac{1}{4} = \frac{1}{48000}$.

Bronce-Mayo, gold washing, dpt. Puno, prov. Caravaya, dist. Ituata.

Buyalmasi, rocky hill with mineral of gold in Castrovireyna, dpt. Huancavelica.

Cabana, gold-mine, dpt. Libertad, prov. Pataz, dist. Parcoy, E. of Parcoy; produce, $\frac{3}{4} = \frac{3}{48000}$.

Cacha, gold-mine in the mineral-ground of Pacon, dpt. Ancachs, prov. Huaylas, dist. Caras.

Cachimayo, Grande,
Cachimayo, Pepuno, } 2 gold-washings, dpt. Puno, prov. and dist. Sandia.

Cajatiri, gold-washing in river of same name, dpt. Puno, prov. Caravaya, dist. Ayapata.

Cajon, El, gold-mine, dpt. Libertad, prov. Pataz, dist. Parcoy; produce, $\frac{7}{8} = \frac{7}{96000}$.

Calaorco, mine of gold, silver and lead, dpt. Libertad, prov. Huamachuco, dist. Mollepata.

Callani, gold-washing, dpt. Puno, prov. Sandia, dist. Patambuco.

Camante, hill containing gold-mineral, prov. Caravaya, close to Marcapata, considered very rich; there was formerly a village at the foot of the hill, but now all is deserted.

Cancarachi, a run of loose auriferous ground, dpt. Puno, prov. Sandia, dist. Phara.

Cangali, very rich gold-washing, between Versailles and the Carrisal, dpt. Puno, prov. Caravaya.

Capacurco, cerro said to be rich in gold, near Mercedes, dpt. Puno, prov. Caravaya.

Caravaya, province in which mines and washings of gold are so abundant that during the Spanish rule in Peru, they produced more than 33 millions of dollars in value. Nuggets were found up to 100 lb. weight. Unfortunately (now) these riches are rendered inaccessible by the horrible and dangerous tracks, improperly called roads, which are the only means of transit over a great part of this province, and which are impassable on horse or mule back. This renders the conveyance of provisions and other necessaries for mining enormously expensive.

Carbon Mayo, gold-washing, dpt. Puno, prov. Caravaya, dist. Ituata.

Carhuapari, gold-mine, dpt. Libertad, prov. Pataz, dist. Parcoy; produce, $1\frac{1}{2} = \frac{3}{24000}$.

Caridad, gold-mine to the E. of Alpacay, in the Cerro of Tiquimbre, dpt. Arequipa, prov. Condesuyos, dist. Yanaquihua.

Carmen, gold-mine, dpt. Libertad, prov. and dist. Huamachuco; produce, $\frac{2}{25} = \frac{2}{300000}$.

Cayetano, San, gold-mine to the N. of Pataz, dpt. Libertad, prov. and dist. Pataz; produce, $3\frac{3}{4} = \frac{15}{48000}$.

Ccollota, gold-mine to the S. of village of Uco, dpt. Ancachs, prov. Huari; produce, $\frac{1 \text{ to } 10}{16} = \frac{1 \text{ to } 10}{192000}$.

Cementerio, gold-mine near the mineral-ground of Chaluma, dpt. Puno, prov. Sandia, dist. Phara.

Cerro Blanco, hill containing mineral of gold and talc, 3 leagues N. of Nasca. Was worked to a depth of 600 mètres (? length) and has given great riches; not worked now, for want of a ventilating shaft.

Cerro Colorado, gold-mine and aventadero, dpt. Puno, prov. Sandia, dist. Phara.

Cochacocha, mineral-ground of gold, in the rocky chain of hills of Ocongate, dpt. Cuzco, prov. Quispicanchi, dist. Marcapata.

Coñamuro, gold-lodes and aventadero, dpt. Puno, prov. Caravaya, dist. Usicayos.

Consuelo, gold mine in the rocky hill of Tiquimbre, dpt. Arequipa, prov. Condesuyos, dist. Yanaquihua, E. of this village.

Contramina, gold-mine, dpt. Libertad, prov. Pataz, dist. Parcoy, lies to the N. of this village; produce, 4.

Corihuacta, gold-mine in the rocky hill of Julcani, dpt. Huancavelica, prov. Angaraes, dist. Lircay.

Corte, gold-mine, dpt. Libertad, prov. and dist. Pataz, N. of this village; produce, $\frac{1}{2} = \frac{1}{24000}$.

Cotani, gold-lodes, dpt. Puno, prov. Sandia, dist. Phara.

Crucero, gold-mine dpt. Libertad, prov. Pataz, dist. Parcoy; produce, 1.

Cuatro Velas, gold-mine in the rocky hill of Pumahuillca, dpt. Ancachs, prov. Santa, dist. Casma.

Cuchipampa, gold-washing, dpt. Puno, prov, Sandia, dist. Patambuco.

Cuñera, gold-mine, dpt. Libertad, prov. and dist. Pataz; produce, $2\frac{1}{2} = \frac{5}{24000}$.

Cutini, gold-washing and aventadero, dpt. Puno, prov. Sandia, dist. Phara.

Chaluma, rich and abundant lodes and washings of gold, but road to them very bad, on river of the same name, dpt. Puno, prov. Sandia, dist. Phara.

Chanabaya, hills with minerals of gold and silver, adjoining the coast of Chucumata, to the W. of Pica. Many and rich veins of both metals, which were worked in ancient times, 22 leagues from Pica and 9 from Saromal, dpt. Tarapacá.

Chaypi, the hills near this village contain many lodes of gold, silver, copper, &c.; alt., 10515 ft.; 14 leagues from Coracora, and 15 from Chala.

Chimboya, gold-lode, dpt. Puno, prov. Caravaya, dist. Corani.

Chinchil, hill with gold-mineral, ½ league W. of Parcoy, dpt. Libertad, prov. Pataz, dist. Parcoy.

Chincho, mine of gold and silver, N.E. of village of San Márcos, dpt. Ancachs, prov. Huari, dist. San Márcos; produce, 25 to 500.

Chinchuragra, gold-washing in the ravine of Ninamayhua, dpt. Ancachs, prov. Huari, dist. Uco.

Chocto, mine of gold and silver, N.N.W. of the village of Chacas, dpt. Ancachs, prov. Huari, dist. Chacas; produce, 100 to 800.

Chontabamba, gold-washing and small farm, dpt. Puno, prov. and dist. Sandia.

Chucaque, gold-mine, dpt. Libertad, prov. Pataz, dist. Soledad; produce, $2\frac{3}{8} = \frac{19}{96000}$.

Chuchumaray, gold-mine, to the W. of Parcoy, dpt. Libertad, prov. Pataz, dist. Parcoy.

Chuquibamba, gold-washing, at alt. 8934 ft.

Espíritu Santo, gold-mine in rocky hill of Tiquipa, E. of Alpacay, dpt. Arequipa, prov. Condesuyos, dist. Alpacay.

Fraylones, gold-mine to the W. of Parcoy, dpt. Libertad, prov. Pataz, dist. Parcoy, produce, 3.

Gallinazo, mine of gold, silver, and lead, dpt. Libertad, prov. Huamachuco, dist. Mollepata.

Gigante, rocky hill containing gold of 17 carats, dpt. Piura, dist. Agabaca.

Huanacauri, rocky hill with gold-ore, at alt. 13,858 ft., dpt. Cuzco, prov. Paucartambo, 1 league S. of Paucartambo.

Huanay, gold-lodes, locality not stated.

Huanca, rocky hill with gold-ore, dpt. Ancachs, prov. Huaylas, dist. Macate.

Huanco-calini, gold-lode, dpt. Puno, prov. Caravaya, dist. Usicayos.

Huano-huano, rocky hill with gold-ore, dpt. Arequipa, prov. Camaná, near snowy mountain of Achatayhua.

Huarauya, mine of gold, silver, and lead, dpt. Libertad, prov. Huamachuco, dist. Mollepata.

Huasacache, gold-mine in rocky hill of this name, dpt. and prov. Arequipa, dist. Socabaya; produce, $1\frac{7}{8} = \frac{15}{98000}$.

Huaycho, gold-mines, dpt. Ancachs, prov. and dist. Pallasca.

Huayllura, gold-mining settlement discovered in 1827, dpt. Arequipa, prov. de la Union, dist. Sayla, produced in three years more than six millions of dollars: now is reduced almost to nothing by want of capital.

Huayna-potosí, gold-lode, dpt. Puno, prov. Caravaya, dist. Crucero.

Humpiri, aventadero, dpt. Puno, prov. Sandia, dist. Phara.

Huycho, or Llamoc, a mountain very rich in gold-ore, dpt. Ayacucho, prov. Parinacochas, dist. Colta. At its foot runs the river Huancahuanca, whose sands contain gold in grains and powder. For a length of 4 leagues along its slopes its altitude is about 13,124 ft. It was worked with great profit before the year 1820 (i. e. before the War of Independence). This mountain lies between the villages of Lampa, Corculla and Oyolo; and serves as a boundary to these districts. At its base lie deep ravines, through which flow the rivers Huancahuanca and Pomatambos; these ravines are almost inaccessible. To the mineral-ground the only access is by way of Colta, and this by a dangerous and narrow defile. When a road is made up to this mineral-ground, it is believed that it will be another California.

Incacancha, rocky hill containing gold-ore; adjoining the estate of Churu, dpt. Cuzco, prov. Paucartambo, alt. 13,176 ft.

Janca, village 10 leagues from Huarmey, dpt. Ancachs, prov. Santa, dist. Huarmey. Near it is the mouth of a mine on lode of ferruginous quartz with a little gold.

Jancas, another village, dpt. Ancachs, prov. Santa, dist. Huarmey. Near it in the ravine of Culebras is a poor gold-mine. At ½ a league from this same village, and 3 leagues from the estate of Cusmo, are some mines of silver and gold, which produce, silver $1 \cdot 8 = \frac{18}{1200000}$, and gold $1 \cdot 37 = \frac{137}{1200000}$.

Jebon de San Pedro, rocky mountain with gold-ore, dpt. Piura, prov. Ayabaca.

Juan, San, gold-mine in rocky hill of Tiquimbre, to the E. of Alpacay, dpt. Arequipa, prov. Condesuyos, dist. Yanaquihua.

Juan, San, del Oro, gold-washing, dpt. Puno, prov. Sandia, dist. Quiaca.

Lanconsillo, rocky hill with gold-ore, dpt. Ancachs, prov. and dist. Santa.

Lavador, gold-mine, dpt. Libertad, prov. Pataz, dist. Uchumarca; produce, 7.

Llacuabamba, gold-mine, dpt. Libertad, prov. Pataz, dist. Soledad, produce, 15.

Lloqueta, gold-washing, dpt. Puno, prov. Sandia, dist. Patambuco.

Machicamani, river and gold-washing, dpt. Puno, prov. Sandia, dist. Phara.

Macon, rocky mountain with gold-ore, 5 leagues from Taquilpon, dpt. Ancachs, prov. Huaylas, dist. Macate, which dist. is very rich in mountains containing minerals of silver and other metals.

Maria, Santa, gold-mine, dpt. Libertad, prov. and dist. Pataz, N. of village of Pataz; produce, 16; now full of water.

Milagro, rocky hill or mountain with gold and silver ore, 5 leagues from Taquilpon, dpt. Ancachs, prov. Huaylas, dist. Macate.

Mina, Santa, mine of gold, silver, and lead, dpt. Libertad, prov. Huamachuco, dist. Mollepata.

Mira, aventadero, dpt. Puno, prov. Sandia, dist. Phara.

Misrito, two gold-mines to the N. of Parcoy, dpt. Libertad, prov. Pataz, dist. Soledad; produce of one $\frac{1}{2} = \frac{1}{24000}$, of the other $\frac{7}{8} = \frac{7}{96000}$.

Mocha, gold-mine at the foot of the western or coast range of Andes, dpt. and dist. Tarapacá.

Monserrate, aventadero, dpt. Puno, prov. Sandia, dist. Phara.

Montebello, gold-mine and washing, dpt. Puno, prov. Sandia, dist. Phara.

Mucumayo, veins and washings of gold, dpt. Puno, prov. Caravaya, dist. Ituata.

Naviceda, rocky hill or mountain with gold-ore, dpt. Piura, prov. Ayabaca.

Negro, aventadero, dpt. Puno, prov. Sandia, dist. Phara.

Ninamayhua, a ravine in which are various gold-washings. It lies behind the mountain of San Cristóbal de Uchusinga, dpt. Ancachs, prov. Huari.

Ocobamba, gold-mine to the W. of Parcoy, dpt. Libertad, prov. Pataz, dist. Parcoy.

Ocongate, village or small town, capital of dist. of same name, in prov. Quispicanchi, dpt. Cuzco, alt. 11,368 ft. In its neighbourhood are mines of gold. There are gold-washings in the river, and gold is found in the sands of the water-courses that supply the village.

Oroblanco, two gold-mines, dpt. Libertad, prov. Pataz, dist. Soledad; of produce one gives 5, and the other 7; the latter has a "heading" driven.

Pablobamba, gold-mine, dpt. Puno, prov. Sandia, dist. Quiaca.

Palmadera, mineral-ground containing gold-ore, dpt. Arequipa, prov. de la Union, dist. Sayla.

Pampa blanca, gold-washing, dpt. Puno, prov. Sandia, dist. Poto.

Pariahuanca, mine of gold, silver, and lead.

Pilcopata, or Huasampilla, river which, joined with the Piñipiñi, forms the river Madre de Dios, near the estate of San Nazario. It has gold-washings, and there are veins of gold-ore in the adjoining mountains. It rises in the snowy mountains of Pucara, dpt. Cuzco.

Piquitiri, river tributary to the San Gavan. Its sands are full of gold, of which there are washings on it, dpt. Puno, prov. Caravaya.

Polvadera, gold-mine to the N. of Pataz; produce, 1; dpt. Libertad, prov. and dist. Pataz.

Pomamachay, gold-mine, dpt. Libertad, prov. Pataz, dist. Parcoy; produce, 3.

Pomemachui, rocky hill with gold-ore, dpt. Piura, prov. Ayabaca.

Poto, a district of the prov. Sandia (since 5 Feb. 1875), (formerly included in prov. Asángaro) dpt. Puno, noted for its many rich aventaderos or aventadores.

Potoche, rocky hill or mountain with veins of silver, copper, and gold, dpt. and prov. Huancavelica.

Pucara, an estate in whose neighbourhood are mines of gold on the river Huasampilla or Pilcopata, dpt. Cuzco, prov. Urubamba, dist. Maras.

Pucaracra, (1) gold-washing in the ravine of Ninamayhua, dpt. Ancachs, prov. Huari, dist. Uco.

Pucaracra, (2) two gold-mines S. of the village Uco, dpt. Ancachs, prov. Huari, dist. Uco; produce, $\frac{1}{16}$ to $\frac{5}{8}$ = $\frac{1 \text{ to } 10}{192000}$.

Pucaramayo, gold-washing, dpt. Puno, prov. and dist. Sandia.

Puihuan, see Puyhuan.

Pulipuli, gold-mine, dpt. Puno, prov. Sandia, dist. Phara.

Pullani, river and gold-washing, dpt. Puno, prov. Caravaya, dist. Usicayos.

Pusupunco, aventadero, dpt. Puno, prov. Sandia, dist. Phara.

Puyhuan, two gold-mines, to the N. of Parcoy; produce of one of these was 50, but it is now filled with water, of the other the produce is 4; dpt. Libertad, prov. Pataz, dist. Parcoy.

Quello-mayo, gold-washing, dpt. Puno, prov. Caravaya, dist. Ayapata.

Quenamari, vein of gold-ore, dpt. Puno, prov. Caravaya, dist. Ajoyani.

Quinua, gold-mine; produce 1, dpt. Libertad, prov. Pataz, dist. Parcoy.

Quiquini, gold-washing, dpt. Puno, prov. Sandia, dist. Patambuco.

Quiquis, gold-mine to the S. of village of Uco, dpt. Ancachs, prov. Huari, dist. Colasay.

Recompensadora, lodes and mine of gold, near Capacurco (q. v.), dpt. Puno, prov. Caravaya.

Rey, (1) mine of gold, silver, and lead, dpt. Libertad, prov. Huamachuco, dist. Mollepata.

Rey, (2) gold-mine in rocky mountain of Tiquimbre, E. of Alpacay, dpt. Arequipa, prov. Condesuyos, dist. Alpacay.

Riquísima, gold-mine in the rocky mountain of Tiquimbre, to the E. of Alpacay, dpt. Arequipa, prov. Condesuyos, dist. Alpacay.

Rosa, Santa, mine of gold and silver, to the N.E. of village of San Márcos; produce, 25 to 500, dpt. Ancachs, prov. Huari, dist. San Márcos.

Rosario, (1) gold-mine, N. of Pataz; produce 3, dpt. Libertad, prov. and dist. Pataz.

Rosario, (2) aventadero, dpt. Puno, prov. Sandia, dist. Phara.

Rosario de Guadalupe, rocky hill with gold-ore, dpt. Piura, prov. Ayabaca.

Rurichincha, mineral-ground very rich in silver and copper, with a little gold. In the ravine of Mallas, S.W. of village W. of Huari, at foot of the western or coast range of the Andes, dpt. Ancachs, prov. and dist. Huari; some mines here give as much produce as 50.

Sagrario, gold-washing, dpt. Puno, prov. Caravaya, dist. Usicayos.

Santiago, gold-washing, dpt. Puno, prov. Sandia, dist. Patambuco.

Sayllapata, aventadero, dpt. Puno, prov. Sandia, dist. Patambuco.

Sillicucho, vein of gold-ore, dpt. Puno, prov. Caravaya, dist. Crucero.

Taccuma, gold-washing, dpt. Puno, prov. Caravaya, dist. Usicayos.

Taquilpon, an estate 5 leagues from Macate, dpt. Ancachs, prov. Huaylas, dist. Macate. In the neighbourhood of, and up to 10 leagues distance from this place, are many mountains containing minerals of gold, silver, and other metals.

Tomas, Santo, mine of gold, silver, and lead, dpt. Libertad, prov. Huamachuco, dist. Mollepata.

Torre, gold-mine, dpt. Libertad, prov. Pataz, dist. Parcoy; produce, 2.

Tranca, aventadero, dpt. Puno, prov. Sandia, dist. Phara.

Trapiche, gold-washing, dpt. Puno, prov. Sandia, dist. Quiaca.

Tumapuquis, 2 mines of gold and silver, to the N.N.W. of village of Chacas; produce, 100 to 800, dpt. Ancachs, prov. Huari, dist. Chacas.

Uchusinga, San Cristóbal de, rocky hill or mountain containing gold-ore, at $\frac{1}{2}$ league from the village or small town of Uco, dpt. Ancachs, prov. Huari, dist. Uco.

Uco, a district of the prov. Huari, dpt. Ancachs. Situated on the right-hand side of the river Puccha, looking down-stream. Is very rich in mines of gold.

Ucucuntaya, gold-mine, dpt. Puno, prov. Caravaya, dist. Ayapata; the lode bears the same name.

Ujina, or Pereyra, a mountain in the western or coast range of the Andes, near Huatacondo, dpt. Tarapacá. It has rich mines of copper, and on the surface is found sand containing gold. On its slopes is found the rocky hill or mountain of Chiclin de Sihua, a rich mineral-ground of gold, of magnetic iron-ore, and of sulphate of alumina.

Umabamba, gold-lodes and aventadero, dpt. Puno, prov. Caravaya, dist. Usicayos.

Venditani, gold-washing, dpt. Puno, prov. Caravaya, dist. Coasa.

Ventanilla, mine of gold and silver to the N.E. of the village of San Márcos; produce from 25 to 500, dpt. Ancachs, prov. Huari, dist. San Márcos.

Vicente, San, gold-mine, produce $1\frac{3}{4} = \frac{7}{48000}$, dpt. Libertad, prov. Pataz, dist. Soledad.

Vilcabamba, gold-washing, dpt. Puno, prov. Sandia, dist. Patambuco.

Yanahuanca, mineral-ground, with silver-ore, and some veins that contain a little gold, dpt. Ancachs, prov. Huaras, dist. Ayja.

Yanamayo, river and gold-washing, dpt. Puno, prov. Caravaya, dist. Coasa.

Yanaracra, gold-mine, dpt. Libertad, prov. Pataz, dist. Parcoy; produce $\frac{1}{2} = \frac{1}{24000}$.

Yerbaverde, gold-mine, dpt. Libertad, prov. Huamachuco, dist. Mollepata, lies E. of Mollepata.

Yucuri, gold-washing, dpt. Puno, prov. Caravaya, dist. Coasa.

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GLOSSARY.

Almocáfre (U. S. Colombia), a kind of hoe used in placer mining (p. 240).

Altai, &c. (Mongol), gold.

Amalgamating barrel, see p. 1060.

Amas lichin (Sumatra), nugget-gold.
Amas muda „ inferior gold.
Amas sungei-abu „ nugget-gold.
Amas supayang „ vein-gold.
Amas urei „ gold-dust.

Amurang (Ceylon), gold-ore.

Anna (India) = $1\frac{1}{2}d.$

Areng (Borneo), pay-dirt, which is a yellowish gravelly earth, sometimes containing also diamonds.

Arrastra, a circular enclosure paved with stones, about 12 ft. diam., on which mineral is ground by mules dragging round large heavy stones. It is a very slow and crude apparatus.

Arroba (Brazil) = 32·37 lb.

Aruppukarans, a gold-washing caste in Madras.

Aventadero or *aventador* (in Peru), a slide of loose ground containing alluvial gold.

Bahar (Malay Pen.) = 4 cwt.

Bar, a hard ridge of rock crossing the bed of a stream, on the upper side of which gold is likely to be deposited.

Barranco (Venezuela), a mining shaft.

Barrel quartz, quartz rock having a corrugated form.

Batea, a gold-washing bowl (see p. 858).

Battery, a set of stamps (see p. 1000).

Battu-uji (Malay), touchstone.

Batu kawi (Sumatra), a red stone supposed to be an infallible sign of gold.

Bed-rock, the solid hard rock underlying loose and incoherent strata.

Bench, a terrace on the side of a river, and having at one time formed its bank. Auriferous benches are termed reef-wash (q. v.) in Australia.

Beneficio (Argentine Rep.), productive ore.

Beting, quartzose-gold matrix of the Malays.

Biliong, the Malayan adze.

Blanket-table, see p. 1052.

Block reefs (Australia), reefs showing frequent contractions longitudinally.

Bolivar (Venezuela) = 1 franc or $9\frac{1}{2}d.$

Bonanza, an aggregation of rich ore in a mine.

Bongkal (Straits Set.), a gold weight = 832·84 gr.; 20 *bongkals* = 1 *catty*.

Bottom, see Bed-rock.

Brownstone (Australia), decomposed iron-pyrites.

Buck stone (Australia), non-auriferous rock.

Buddle, see p. 1080.

Cacho de bateador (U. S. Colombia), a bo.t-shaped piece of horn used in gold-washing.

Cacó (Brazil), white sugary quartz.

Cajon or *Caxon* (Bolivia) = 50 *quintals*.
„ (Peru) = 60 „
„ (Chili) = 64 „
1 *marco* of gold per *cajon* of ore = 2 oz. 14 dwt. $10\frac{2}{3}$ gr. per ton.

Candareen (China) = $\frac{7}{10}d$.

Canga (Brazil), a rock composed of sharp-cornered, angular (rarely slightly rounded) fragments of mi:aceous iron, specular iron, and magnetic oxide of iron, held together by red, yellow, or brown ochreous cement; it is often very auriferous, and sometimes contains scales of talc and chlorite, and stray fragments of *itacolumite*. It is widely and deeply distributed in valleys and on hill-slopes and summits, and has resulted from glacial action.

Canoa (Brazil), a platform used in gold-washing.

Carga (Mexico), variously given as 3 *quintals* = 312 lb., 12 *arrobas* = 300 lb., and 12 *panegas* of 12 *almudas* = 18 bushels.

Cascajo (Venezuela), a decomposed schist, on which the pay-dirt lies.

Cascalho (Brazil), gravel, which, when auriferous, is composed of quartz fragments.
Cascalho virgem, the deeper and older gravel of a river-bed.

Cash (China) = $\frac{7}{100}d$.

Casing, material found between a reef and its walls.

Catty (China) = $1\frac{1}{3}$ lb. av.

Catty (Straits Set.), a gold weight = 2·9818 lb. troy.

Cement, very widely applied to all auriferous conglomerates.

Cerro (Spanish), a rocky hill.

Chinna (Kanada), gold.

Chacra (Bolivia), an inheritance of gold.

Chañgkul (Sumatra), a miners' hammer.

Chocque (Aymara), "gold," whence the local names Chuqueapo (now La Paz), Chuqueaguillo, Chuquesaca (now Sucre).

Chonkole, the Malayan spade.

Clavo (Mėxico), a very rich spot of small horizontal extent, but constant in depth, i. e. a "pay chimney."

Colour, minute traces or individual specks of gold.

Contour-race, a leat or water-course following the contour of the country.

Country or *country-rock*, the geological strata on each side of a reef or vein.

Cradle, see p. 858.

Crevicing, picking out the gold caught in cracks and crevices in the rocks over which it has been washed.

Creadero (Span. Amer.), an "indicatio ' of the existence of gold.

Crusade = $\frac{1}{32}$ oz. of gold, value 2*s*. 6*d*., or = 400 *reis* = 1*s*. $9\frac{1}{4}d$.

Curi (Ecuador), gold, whence Curaráy river.

Dalama (Zambesi), gold.

Daric (Persian) = 123·7 gr., value 1*l.* 1*s.* 10½*d.*

Denounce (Mexico), to obtain a mining grant for a certain spot.

Dip, the downward inclination of a vein.

Doilia (Russia) = 0·685 gr.

Dolly (Australia), a springing pole about 50 ft. long, fixed to the tops of posts set in the ground, and having at the small end a rope, handle and shoe attached, for smashing rock on an anvil put beneath. The spring of the pole greatly reduces the labour. Another form is used in the Philippines (p. 368).

Dorongee [*duruni*] (Assam), a gold-washing trough.

Drift, (1) a level; (2) very loose, friable, alluvial deposit, requiring close timbering to work; (3) glacial drift, alluvial deposits formed by ice.

Drifting, working a mine by means of driving tunnels on it.

Duin, gold-washing dish used in Jashpur, India.

Dulan (Borneo), circular concave trays for washing gold.

Faiscadore (Brazil), a gold-washer.

False bottom, (1) a movable bottom or floor in a buddle, battery, or sluice; (2) in alluvial mining, a stratum on which pay-dirt lies, but which has other bottoms below it.

Feather-edge (New Zealand), a local term for the passage from a false to a true bottom (p. 818).

Float-gold, gold in tiny thin scales, which float on running water.

Floating reef, masses of bed-rock found displaced and lying amongst alluvial detritus.

Florin (Holland) = 1*s.* 8*d.*

Floured mercury, mercury which has become granulated and each grain coated with a film of sulphide, destroying its amalgamating power (see p. 1030).

Flour-gold, the finest alluvial gold, sometimes found as a coating on quartz pebbles in cement.

Fossicking, almost identical with crevicing (q. v.).

Fuang (Cochin China) = 3¾*d.*

Gamella (Brazil), a wooden bowl, about 2 ft. wide at the mouth, and 5 or 6 in. deep, used for washing gold out of the auriferous matter collected in sluices and in river-sands.

Garimpeiro (Brazil), a gold-seeker and smuggler.

Gogo (Philippines), a plant whose juice is said to catch fine gold.

Gouge (Nova Scotia), a narrow band of slate next the vein, which can be extracted by a thin, long pointed stick, and yields gold (p. 88).

Grating, a perforated iron sheet or wire webbing, enclosing the stamper-box.

Gravel, any broken-down rock, auriferous gravel being generally quartzose.

Greda (Venezuela), pay-dirt—a yellow ferruginous clay, containing nuggets and small grains of gold.

Ground-sluice, see p. 868.

Gua (Huarpe), gold; hence *guachi*, mountain of gold; *gualilan*, land of gold.

Guaca (U. S. Colombia), a mining tunnel.

Gutter, the lowest portion of a lead, which contains the most highly auriferous dirt.

Hade, dip.

Hatter (New Zealand), a miner working on his own account.

Headings, coarse gravel or drift overlying the wash-dirt.
Head-race, an aqueduct for bringing a supply of water.
Hemma (Sanskrit), gold.
Honna (Kanada), gold.

Ita, Japanese gold-washing board.
Itabirite (Brazil), a rock composed of micaceous specular iron-ore (rarely laminated) and a little oxide of iron and manganese with quartz disseminated; in the pulverulent form it is called *jacutinga*. Both carry free gold.
Itacolumite (Brazil), a rock composed chiefly of fine-grained quartz, united by thin laminæ of chlorite and talc.
Itambamba (Brazil), a plant (? *Solanum sp.*) whose juice is thought to help catch fine gold.

Jacutinga (Brazil), a pulverulent variety of *itabirite.*
Jhoras, an Indian gold-washing caste (see pp. 325, 328, 329).
Joren, a scoop-shaped bamboo basket used for carrying auriferous gravel in Japan.
Julgars, an Indian caste whose employment is gold-washing.

Katouti, gold-washing trough of the N. W. Provinces, India.
Kisye (Malay), rattan sieves used in gold-washing.
Kopeck (Russia) = 0·38*d*.
Kua, specially shaped hoes used for working gravel in the sluice in Japan.

Laminæ (Span. Amer.), scale gold.
Lavadero (Span. Amer.), an alluvial gold-washing.
Lavra (Brazil), a small alluvial washing.
Le (China) = 486·176 yd.
Lead, a well-defined bed of pay-dirt.
Leadings (Australia), barren drift overlying pay-dirt.
League (Brazil) = $3\frac{3}{4}$ miles.
League (Spanish) = 20,000 Spanish ft. = 5572 mètres = 6093 yd.
Léang (China) = $1\frac{1}{3}$ oz. av.
Ley de oro (Mexico, &c.), properly the fineness of the gold, but apparently also applied to the assay value of an ore.
Lilin kalulut (Malay), a wax used by gold assayers (p. 364).
Long-tom, see pp. 860–2.

Mace (China) = 7*d*.
Manta (Nicaragua), a surface deposit of broken quartz, worked for gold.
Maraye (Argentine Rep.), grinding mortar used by the Indians for reducing quartz.
Marco or *Marc*, see Spanish goldsmiths' weights.
Mark (Austria), old weight, 0·618 lb. av.
Mas muda (Malay), "young" gold, or gold below 8 *mutu*.
Mas tuah (Malay), "old" gold, or gold from 8 to 10 *mutu* (p. 364).
Mergulhar (Brazil), washing auriferous river-sands.
Miam (Straits Set.), a gold weight = 52 gr.; 16 *miams* = 1 *bongkal*.
Milreis (Brazil) = 2*s*. 3*d*.

Moco de hierro (Venezuela), a highly ferruginous rock, assuming the form of a conglomerate, a grit, a breccia, or even a pisolitic brown iron-ore; it always consists mainly of limonite and earthy red hæmatite, with pebbles and angular fragments of quartz, schist, and felstone. In its decomposed form it is known as *tierra de flor* (q. v.).

Monton (Mexico), 17 *quintals* = 1560 lb.

Mullock (Australia), angular débris of the country rock filling a fissure.

Mundic, iron-pyrites.

Mutu (Malay), a term denoting the degrees of fineness of gold (p. 364).

Napal, indurated white clay carrying auriferous quartz streaks in the Malay Peninsula. Called also steatite.

Nariyas, gold-washers of the N.W. Provinces, India.

Nega (Thibet) = $\frac{1}{8}$ lb.

Nekoza, straw-mats specially woven, used for catching gold in the sluices in Japan.

Nugget, a sizable rounded piece of native gold.

Oitavo (Brazil) = 55·34 gr. troy; 8 *oitavas* = 1 *onça*.

Omorotchi (Russia), birch-bark skiffs.

Onça (Brazil) = 442·72 gr. troy.

Orang gulla (Sumatra), miners.

Oro corrido (U. S. Colombia), alluvial gold.

Paint-gold, gold coating quartz pebbles in cement.

Pan, see p. 856.

Panella, see *Gamella*.

Paret (Borneo), a mine.

Patach (Brazil), 8·65*d.*

Patea, see *Batea*.

Pay-dirt, that portion of an alluvial deposit which contains gold in paying quantity.

Peña (U.S. Colombia), a more or less decomposed felspar or gneiss, coloured by iron, and yielding gold as far as decomposition has taken place.

Pepita (Span. Amer.), a gold-grain.

Perjong, the Malayan crow-bar.

Peso (Mexico) = 4*s.*

Phátáng (N. Himálaya), a quantity of gold-dust melted into a lump, value about 8 rupees (16*s.*), and used as currency.

Phukpa (Thibet), miners' caves.

Piastre (old Spanish) = 37·647*d.*

Picul (China) = $133\frac{1}{3}$ lb. av.

Picul (Philippines, &c.) = $139\frac{1}{2}$ lb.

Picul (Siam) = $135\frac{1}{2}$ lb.

Pie (India) = $\frac{1}{8}$*d.*

Piedra morada, see *Porfiro*.

Piedra negra (Venezuela), greenish-grey felstone.

Pillah (Bokhara), gold.

Playa (Span. Amer.), a level bank.

Polvillos (Mexico), tailings.

Pon (Tamil), gold.

Porfiro or *porfido* (Venezuela), a reddish, pink, or brown ferruginous hornstone, sometimes becoming jasper, occasionally containing crystals of iron-pyrites, or cavities left by their decomposition, and rarely visible gold, but not in payable quantity. It occurs throughout the Caratal district, and is regarded as a favourable indication of gold. It is known also as *quartzo morado* and *piedra morada*.

Pozo (Mexico), winze.

Pud (Russia) = 36 lb. 2 oz. av.

Putti, a gold-washing tray used in Madras.

Putty-stones (America), soft pieces of decomposed rock found in placer deposits (p. 794).

Quartzo morado, see *Porfiro*.

Quebrada (Span. Amer.), a valley.

Quinto (Brazil), royalty on gold-mining.

Race, an artificial water-course.

Rang (Ceylon), gold, whence Rang-galle (from *rang-welle*, golden sand).

Ratrang (Ceylon), melted gold.

Reefing, working auriferous reefs or veins.

Reef-wash, a deposit of wash-dirt spread over an expanse of flat or undulating bed-rock, or lodged in a hollow in bed-rock above the level of the gutter; an Australian term, apparently synonymous with bench (q. v.).

Rega (Brazil), a water conduit or launder.

Rei (Brazil) = $\frac{1}{37}$*d.*

Respaldo (Mexico), wall of a lode.

Riffle or *ripple*, a groove about 1 in. deep at the lower side, diminishing towards the upper, with a width of about 3 in., cut across the riffle-board which forms a false bottom to a sluice, and partly filled with mercury while at work; also small strips of wood nailed across and rising above the floor of a box-sluice.

Rock, often applied to igneous rock-flows met with in deep leads.

Ruble (Russia) = 3*s.* 2*d.*

Rupee (India) = 2*s.*

Saga (Straits Set.), a gold weight = 4⅓ gr.; 16 sagas = 1 *miam*.

Sana birro (W. Africa), gold nuggets.

Sana ku (W. Africa), gold-washing.

Sana manko (W. Africa), gold powder.

Sana mira (W. Africa), gold-rust (? emery).

Sarshoo (Thibet) = ⅜ oz.

Scad (America), a term for a nugget, but not in general use.

Sepé (U. S. Colombia), a porphyroidal clay, stained with iron salts, sometimes covering the auriferous *peña*, and usually of very limited thickness.

Shaking-table, see p. 1070.

Sickened mercury, see *Floured mercury*.

Sludge, mud flowing from a puddling-machine.

Sluice, see p. 862.

Sluice head, a definite measure of water drawn off for use.

Slum or *slimes*, the waste mud flowing from a quartz battery.

Spanish goldsmiths' lb. = 9600 *granos* of $\frac{400}{878}$ troy gr., thus divided :—

12 granos = 1 tomin.	50 castellanos = 1 marco.
8 tomines = 1 castellano.	2 marcos = 1 libra.

Spotted (America, &c.), leads in which the gold is irregularly disseminated.

Stamp, a solid head or weight used for crushing mineral.

Stamper-box, a box, generally of cast-iron, in which the stamps work, and whose sides are fitted with gratings.

Strake, see p. 1052.

Strike, the longitudinal direction of a vein.

Surfacing, working shallow auriferous alluvions.

Suvarna (Sanskrit), gold.

Tabah (Sumatra) a crow-bar used in gold-mining.

Tael (China) = $1\frac{1}{3}$ oz. av.

" " = 5*s.* 10*d.*

Tael (Straits Set.), a gold weight = 832·84 gr.

Tailings, the detrital mud flowing from gold-washing or crushing apparatus.

Tail-race, an aqueduct for conveying away dirty water and tailings.

Tambang (Sumatra), mines.

Tambikir quali (Malay), a black incrustation found on auriferous quartz.

Tan (China) = $133\frac{1}{3}$ lb. av.

Tapanhoacanga, see *Canga*.

Tharu, a gold-washing race in Champaran, Nepal.

Tial (Sumatra) = $610\frac{1}{4}$ gr.

Tical (Burma) = 252 gr.

" " = 2*s.* 6*d.*

Tical (Siam), for gold = 236 gr. troy, or nearly $\frac{1}{2}$ oz.

Tierra de flor (Venezuela), decomposed *moco de hierro* (q. v.), washed down the hill-sides, occupying areas of 100 to 200 acres and 6 to 10 ft. thick, and probably deriving its ferruginous matter from iron-pyrites. It is considered a good indication of alluvial gold.

Toise = 6·395 ft.

Tola (India) = 180 gr.

Torpedo (Dutch Guiana), a sloping iron perforated plate fixed between the long-tom and the riffles in the sluice (p. 861).

Tosca (U. S. Colombia), a volcanic rock overlying the auriferous strata, and considered a good indication.

Tsuru, picks used for loosening the auriferous gravel for washing in Japan.

Underlie, dip.

Vara (Mexico, &c.) = 2·782 ft.

Venéro (U. S. Colombia), a vein or bed.

Volost (Russia), a commune of peasants.

Wash-dirt, the auriferous gravel, sand, clay, or cement in which the greatest proportion of gold is found.

Zolotnik (Russia) = 65·83 gr.

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LONDON: PRINTED BY WILLIAM CLOWES AND SONS, LIMITED, STAMFORD STREET AND CHARING CROSS.