some places without any marked decrease in copper contents; but the length and width of the Rio Tinto deposits are enormous, one of them being more than half a mile in length, and in some places more than 300 feet wide—all solid ore.

In the Tharsis mines, the next in importance, poor ore has been found at much less depth, the lateral dimensions of the deposits being smaller. In most of the smaller mines the ore gets too poor to be worked at a profit at a depth less than 300 feet. One per cent. of copper is generally taken as the limit of workable ore.

The following is a complete analysis of a fairly representative sample of ore from the Rio Tinto mines:—

Sulphur	48·3
Copper	3·44
Iron	43·33
Bismuth	·02
Lime	·34
Lead	1·00
Gold	·00005
Silver	·004
Cobalt	·05
Arsenic	·75
Antimony	·07
Calcium oxide	·23
Manganese	·05
Silica	1·89
Moisture	·48
Selenium	traces.
	99·95405

There are some exceptional deposits which are of a different nature, such as the "Esperanza," near Tharsis, where the copper is found as a sulphide impregnating the slate, but they need not here be mentioned.

The ore is generally sorted by hand into two classes. The richer ore is sent to England and the Continent, to the sulphuric acid manufacturers (who, after burning off the acid, send the residue to the copper works), and the purer ore is generally treated for copper only in proximity to the mines.

Two systems of mining are very generally adopted.

When the gossan is comparatively shallow and the mineral mass is wide, the ore is generally got by open-cast working; the overburden is removed in benches about 30 feet high, and the ore thus laid bare is quarried.

The cost of removing the overburden varies with the nature of the ground and with the facilities for getting proper dumping facilities. The following statement shows the average cost over a whole year in the "Joya" mine, which is worked by the open-cast system. The greater part of the material removed is decomposed porphyry, and, as a rule, fairly hard.

Cost of Removing Overburden at the "Joya" Mine, per Cubic yard in the Solid (calculated on the total quantity removed during 1891).

Labor.—Superintendence	$0.009	
Excavation	0.032	
Loading into waggons	0 049	
Mule-drivers	0.005	
Unloading waggons and repairing roads	0.016	
Various	0.001	—$0·112
Materials.—Explosives		
Baskets (used for loading waggons		
Railway material		
Waggon "		
Oil and grease		
Various		— 0·011
Shops		0·006
Stable expenses (mules)		0·013
Tools		0 003
Amortisation of railway material		0·005
Total cost per cubic yard		$ 0.15

The open-cast working is certainly the best system in mines where the overburden is shallow and the deposit wide. The limit at which the removal of overburden becomes unprofitable is generally put at 4 cubic yards of overburden for every ton of ore laid bare. The cost of quarrying the ore, after having laid it bare, may be taken as follows, exclusive of general charges:—

Cost of Quarrying Ore in the Open-cast in the "Joya" Mine per Ton of 1000 Kilos (Average for the Year 1891).

Breaking the Ore.—Miners	$0.038	
Materials, explosives	0.012	
Shops	0.004	
Tools	0 005	—$0.059
Loading into waggons		0.038
Weighing		0.003
Total cost per ton, put into waggons and weighed		$0 10

Examples of open-cast working are found at the Rio Tinto (south lode), Santo Domingo, Tharsis (north lode, Sierra Bullones, and centre lode) La Zarza, La Joya, Las Herrerias, Lagunazo, etc.

When the proportion of overburden is too great, the mine is generally worked on the pillar-and-stall system. The lode is divided off vertically in floors, 30 to 40 feet apart, and in each of these floors galleries and cross-galleries are driven, intersecting one another at right angles, leaving large pillars of mineral to support the roof between the floors. The roof is generally left about 12 to 15 feet thick, and the square pillars have sides of 15 to 20 feet, the galleries being of the same width as the pillars, and about 20 feet high. It is evident, that by adopting this system of working, a large quantity of ore is left in the mine; taking floors 35 feet apart, with a roof of 12 feet, galleries 23 feet high and 16 feet wide, and pillars with sides of 16 feet, the quantity of ore extracted by means of the galleries is only one-half of the total quantity. In several mines considerably less than one-half is extracted. It is generally maintained by those who adopt the pillar-and-stall system that after honeycombing the mass, more ore may be gained by robbing the pillars and roof. This is, however, a very dangerous operation in mines where the lode is nearly vertical, where the width is considerable, the ore very heavy (specific gravity about 5), and where often ten to twenty floors are formed one above another. Only in one mine (the Carpio mine) has this been done, and the result was not encouraging. Only four floors had been formed, yet, although a good deal of ore was extracted by robbing, still, by far the greater part remained in the mine, and could not be got out, the comparatively great height of the galleries being a great element of danger. That the operation of robbing is a very delicate one is confirmed by the fact that most of the mining companies, after extracting all the ore they could get by means of galleries, and finding their ore reserves disappearing, have determined, instead of robbing the pillars, to remove the overburden and quarry the honey-combed mass in the open air. Instances of this are found in many places. It is needless to say that a great deal of money would have been saved if the overburden had been removed from the beginning.

Another disadvantage in connection with the pillar-and-stall system is the great cost of breaking the ore. Although galleries may be driven of considerable dimensions as long as the ore is firm, still, breaking ore in galleries, especially in hard ore, is always very costly. Whilst the breaking of ore in the open-cast may cost $0.07 per ton, the breaking in galleries will cost, on an average, from $0.52 upwards. When the ore is very hard it may be as great as $0.85. The reasons for this higher cost are too evident to need any mention. A miner will break per shift, in galleries, about ¾ of a ton; in the open-cast he will break from 12 to 15 tons of ore, and even more in favorable cases.

Examples of pillar-and-stall workings are found at Rio Tinto, in the San Dionisio lode; at Tharsis, in part of the north lode, and formerly, in the Sierra Bullones and La Zarza Tharsis (both these lodes are now open-cast); at Lagunazo, in the eastern portion of the lode, at Sotiel-Coronado, Pena de Hierro, Lapilla, Aznalcollar, Coridad, etc.

The Cabezas del Pasto mine is worked on a different system, which allows all the ore to be extracted without any danger and at a low cost; and there seems to be no reason why the system should not be adopted in all places where the pillar-and-stall is now used, and where the height of overburden excludes the open-cast system. The mineral deposit at this mine is about 500 feet long, with a width varying from 20 to 75 feet, the average being about 32 feet. The gossan goes down about 100 feet, and it was, therefore, impossible to work the mine by open-cast. The lode is nearly vertical and approximately in the centre of the mass.

After fairly ascertaining the bearing and extent of the lode, an extraction-shaft and a pumping-shaft were sunk in positions outside of the lode. The dimensions of these shafts were 10 feet by 5 feet and 11 feet by 5 feet. The extraction-shaft was divided by a partition in the centre, so as to accommodate two cages. They were originally sunk to a depth of 230 feet, and subsequently deepened to 350 feet.

The lode was then divided in floors about 65 feet apart. From the extraction-shaft galleries were driven at every floor, cross-cutting the lode entirely. When these galleries reached the ore, narrow galleries were driven east and west, following the hanging-wall (the extraction-shaft being in that wall), along all the sinuosities of the lode, and accurately determining its shape. From these galleries, again, cross-cuts were driven through the lode at every 33 feet. After thus learning the exact shape of the lode, a "side-tie" was driven in the country-rock, alongside the lode and at an average distance of about 15 feet, and from this side-tie cross-cuts were driven towards the lode at regular intervals of 33 feet. The side-tie was kept nearly straight and was used as an extraction-gallery; a tramway of 2-foot gauge, with rails of 30 pounds to the yard, being laid in it. There were various reasons why the gallery along the wall of the lode was not utilized as an extraction-gallery, the two principal ones being its crookedness, and the fact that it became surrounded by "stowing" or "gobbing," which necessitated constant timbering to keep it open. On one of the levels it was, indeed, attempted to make this gallery serve for extraction, but it was found very difficult and expensive, and quite unsuitable.

Both walls of the lode are slate, in which all galleries had to be closely timbered.

When the cross-cuts from the gallery along the hanging-wall had reached the foot-wall they were filled with stone carefully piled up, and new cross-cuts were then driven alongside the first ones; these were again filled up, and again new ones were made, and so on until a complete slice of ore had been removed over the whole length and width of the deposit. All the galleries and cross-cuts had a uniform size of 6 by 6 feet, so that the height of the first slice removed was 6 feet. When this had been accomplished the gallery along the hanging-wall was filled up and a new gallery was driven right above it. From this new gallery cross-cuts were again driven through the mass and filled up the same way as below, but with one important difference: while the first slice of 6 feet had to be broken out of the solid body of ore, the slice next above was now under-cut over its whole area, in fact it was resting on the packing. This made the blasting very much cheaper; so that, whereas the contract price given to the miners in the first slice averaged $0.50 per ton of ore, it was only $0.25 in the slice next above. Again, in the first slice the first cross-cuts in the solid ore cost $0.76 per ton of ore, and the secondary cross-cuts, which were really widening out the first ones, only cost $0.42 per ton. These figures show the enormous advantage of having free sides for the working faces—an advantage, by the way, which is never got in working by pillar-and-stall. After the second slice had been removed a third was taken away in the same manner, and so on until the whole lift of 65 feet was removed. The working was not limited, however, to one lift or level, but three were attacked simultaneously in the same manner; and at the present day the second, third and fourth levels are in active work, and the fifth is in preparation.

It might be expected that some difficulty would be experienced when workings of one floor reach the stowing of the floor above. In practice, however, it is found that the stowing gets so tightly packed as to be quite firm, and with a little additional care it is comparatively easy to mine below it. No galleries nor cross-cuts were made more than 6 feet high and 6 feet wide, and no new cross-cut was started before the adjoining one had been properly filled in.

During the filling-in of the gallery on the hanging-wall a chute was built up in rough stone, above the cross-cut, from the side-tie. Through this chute the ore from the second slice was thrown down to the cross-cut. When the second slice had been removed and the next gallery filled in, these chutes were carried up, and so on; and these always served for sending the ore down to the cross-cuts, and thence to the side-tie, where the ore was loaded into wooden hutches holding about one-half ton each, and subsequently trammed to the extraction-shaft.

The material used for stowing is quartzite. This is quarried on the top of a hill, about 700 yards from the lode. The stone is lowered by means of an inclined plane to the level of the mouths of two special shafts sunk for the purpose of delivering stone to the workings, and extending at present to the third level, with loading platforms at each floor. The stone, loaded in hutches similar to those used for the ore, is lowered in these shafts by means of double drums, with brakes, the full waggon going down pulling up the empty one. The stone required in the fourth level is landed in the third level and trammed through the extraction-gallery of this level. This extraction-level is connected with the workings below by means of winzes; the stone is tipped into the winzes and falls almost at the foot of the workings to be filled up. As the slices are removed these winzes get filled up also, and therefore gradually disappear, while the ore-chutes always get longer. Each level is thus supplied with stone from the floor above, and the stone need never be raised by hand. All the winzes for throwing down stone are made in the hanging-wall; they are about 3 feet square and very securely timbered.

A good deal of small stuff is produced in the quarry. At various times trials were made to use these smalls in filling up, as it seemed a pity to throw them away. It was found, however, not economical to do this, as the smalls were more expensive to handle in the mine than the big stones, and also because stowing done with smalls settles down far too much, and loosens the ore above to a dangerous extent, making a very treacherous roof in the workings higher up.

The stowing with large stones is so firm that no subsidence of the ground over the mine can be noticed, although a very large quantity of ore has already been removed.

This system has now been in operation for eight years, during which a total of 236,000 tons has been extracted. Only one man has been killed by falls of the roof during all this period, which shows that the system is not a dangerous one. All the cross-cuts are kept narrow (6 feet); very few props are used, and even these few are generally taken away before stowing.

The average quantity of ore broken by a miner in this mine is 3 tons per shift of ten hours, as against ¾ ton under the pillar-and-stall system, the difference being due to the ore being always under-cut and requiring little blasting.

The average cost of work in 1891 was, for different parts of the system, as follows:—

	Per Ton
First cross-cuts in the solid ore	$0.76
Cross-cuts	0.42
First cross-cuts in next slice	0.28
Following cross-cuts, etc	0.24

This shows the increased economy in breaking when the ore is under-cut.

The cost of extraction for the year 1890 was as follows:—

Cost per Ton, apart from General Expenses.

Labor.—Superintendence	$0.0128	
Breaking the ore	0.2372	
Loading into waggons and tramming	0.0501	
Engine-men, etc	0.0362	
Stowing	0.1569	
Timbering	0.0152	
Unwatering	0.0048	
Various	0.0078	—$0.521