GOLD FROM MINE TO MINT.

By J. S. Macarthur.

[Read 7th January, 1913.]

The Alchemists used to speak of gold and silver as being noble metals, because they did not rust and they resisted the action of the ordinary common place chemicals which destroy the ordinary common place metals like iron, and copper. The group of noble metals has been enlarged since the day of the Alchemists by the inclusion of platinum, osmium, iridium and a few others. Gold and silver are still by a long way the best known of the noble metals. In nobility gold is distinctly above silver. Neither of them rusts, but silver tarnishes and is attacked by acids that have no effect on gold. As one might expect from these properties we find that gold occurs in nature, not as a combination, but simply as gold. It occurs in yellow masses that may be pounds in weight or may be microscopic but generally as metallic gold. In this it differs from other metals ; we sometimes get silver as metal but, as a rule, it occurs in combination. The other ordinary metals, iron, copper, lead, zinc, tin, all occur in combination and almost invariably as oxide or sulphide.

The one notable compound of gold found in nature is the telluride, a combination of gold and tellurium. At a moderately high temperature the tellurium is driven off and the gold remains. This ore is the only commercial source of gold in which the gold cannot be detected visually.

Oxide of gold can be prepared by chemical means and sulphide can be prepared by chemical means, but neither of these is stable. Each of them on the slightest provocation gets rid of the oxygen or sulphur and again becomes metal.

This metallic character has made gold the longest known and one of the best known metals in spite of its great scarcity. It is so easily identified by the eye and owing to its extreme weight compared with other substances is easily separated (if the grains are at all large) that from the earliest time it has been recognized and used for all sorts of purposes. Its yellow colour and resistance to tarnishing or corrosive action makes it specially suitable for use as a medium of exchange in early days when it it was passed from hand to hand in nuggets or ingots and in latter days as properly coined money.

Until the middle of the 19th Century the whole of the World's supply of gold was got by washing alluvial deposits, but by the time that gold was discovered in California, and soon after in Australia, true gold mining took its rise and gold washing fell slightly into the back ground.

The old picture of the miner washing gravel in the river and getting a few nugget grains of gold per day held good until a generation ago, but the gold miner now-a-days goes down the shaft and works not unlike the coal miner, in a close atmosphere and in surroundings more or less unpleasant.

Let me describe what I have done myself, and I ask you to accompany me to a river in the North of Spain flowing through a mountainous country and over beds of gravel which have been accumulating during past ages.

I take an iron pan about the size of a dairy pan. I place some gravel from the river in the pan and fill it with water, shake vigorously and allow the contents to settle for a few seconds—a clayey, slimy liquid covers the mass of clean gravel —the liquid is poured off and the operation repeated a few times until the water is clear and the gravel clean. I then pick out by hand the larger pieces of gravel and leave in the pan the small gravel and sand. By dexterous washing I reduce what was originally about two or three lbs weight to an ounce, and I now scrutinize the ounce closely and I find a few specks of gold and my happiness varies with the size and number of those specks.

In some parts of the world a living can be made by using pans, but in most cases the pan tests are only the precursor of dredging. After we have proved the river by systematic panning and recorded the amount of gold produced per pan, we begin and instead of working on a few pounds per day, we displace perhaps, one or two thousand tons per day. If we can get 6d worth of gold per ton, we become rich.

Practically all the alluvial gold produced in the world now-a-days is obtained by dredging which is carried out in the rivers of Western America, in New Zealand and even far inland in Australia.

It is generally understood that alluvial gold is the result of the natural weathering of Gold reefs, though some people hold that gold occurs in gravel and that the accretion is caused by a small amount of gold being carried in solution and deposited on the nuclei in gravel.

I do not propose to discuss this subject but only to say I cannot accept that view, because I think that the old view presents fewer difficulties to be explained away. As a matter of fact the order of practice in prospecting is to look for float gold in the beds of streams and work from these up to the gold reef. This was done notably in California many years ago, and has been done quite recently in Yukon territory.

The great main reef of Witwatersrand was not discovered in this fashion, because the country is flat, with little erosion and practically no streams. It was discovered as other gold fields have been discovered in arid regions by the chipping of rocky projections, which formed a long line of outcrop.

Assuming that the gold ore is obtained we may extract the gold in many ways, which may be divided into four principal groups according to the leading principles involved.

As a matter of convenience we may first consider :—

SMELTING. In common with most metals gold may be extracted by smelting, but the proportion of gold in ore is so

small, say one ounce per ton or one part in 30,000, that it would be necessary to smelt a few thousand tons of ore before the crevices at the bottom of the furnace would be filled up and to get over this difficulty a " collector " is used. This collector is invariably a metal such as copper or lead or the sulphide of a metal, called in Metallurgy a " matte."

Suppose we have an ore containing one ounce of gold per ton, it would be commonplace to add metal bearing fluxes to this ore so as to form 10 ton of matte containing all the gold. In turn the matte would yield say one ton of lead, containing the whole 100 ounces of gold. The auriferous lead is then refined and the lead removed by oxidation and absorption at red heat, and the gold being a noble metal and able to withstand the corroding effect of air at a high temperature is left in a state of high purity.

Smelting generally and the operation of cupelling are older than written history. It has been my privilege to find unmistakable records of this work in Portugal, which must date as far back as Phoenician times.

It is possible to re-use the matte and the metal over again but this is seldom done. The gold is rather produced as a byproduct along with copper or lead.

In this connection it is interesting to note that silver which in former times was produced almost wholly on its own account has within the last generation been produced almost wholly as a byproduct in lead and copper mining. Within the last seven or eight years there has been a revival of silver mining in Mexico owing to the development of more favourable conditions of work and to the introduction of more economical methods. The discovery in recent years of the silver deposits at Cobalt in Canada have also led to a large production of silver on its own account.

In this paper I speak generally of gold but as silver resembles gold in many respects its metallurgy runs parallel to the metallurgy of gold. Silver being a less noble metal

than gold its chemical reactions are less clearly defined, but generally what is metallurgically true of gold is true of its weaker and less valuable neighbour.

Doubtless there are differences but they are so highly technical as to be of little interest to a general audience.

There is a noteworthy feature in connection with smelting and refining especially in the case of copper which is worth telling :—The first fraction of metal produced at any operation contains all the gold and most of the silver.

Suppose we have in a furnace a charge of metalliferous material capable of producing ten tons of copper it is probable that the first ton of metal actually reduced will contain not only all the gold but the great bulk of all impurities and the last nine tons will be produced almost pure.

It is almost unnecessary to point out that this action is of first importance in refining.

Another method of gold extraction is to crush the ore to sand, wash away the sand by a regulated flow of water and collect the gold which, being heavy, remains. This is just an imitation of nature in her preparation of alluvial gold.

This method is imperfect in as far as it is not capable of collecting fine gold. It is true that gold is relatively heavy but when any substance exists in a fine state suspended in water its specific gravity matters little for the extreme fineness of the particles involves such frictional resistance in settling that it is impossibly slow and in some cases there is no settlement.

Gold can be prepared in this form called colloidal, artificially, very easily and we have every reason to believe that it exists sometimes in this state in nature. The purple of Cassius is the best known form of finely divided gold in the laboratory but ruby glass is more commonly known and the best kinds owe their colour to finely divided gold.

Perhaps the best known form of finely divided gold is found in toning photographs. The various shades of tone are due to gold being precipitated on the image by various precipitants under varying conditions which modify the tint. Gold may be caused to assume many colours from the yellow of massive gold to the rose-pink of dilute purple of Cassius.

When gold exists in this form it obviously cannot be separated by any means dependent on its specific gravity, and indeed, even its chemical properties seem to be masked.

Gold frequently exists as float—not nearly as fine as colloidal but fine enough to float on water as a scum. The first mention of this in history is when Moses caused the golden calf to be ground to powder suspended in water and drunk by the people.

Gold may also be separated from its ores by amalgamation. In chemistry and metallurgy this word has a separate meaning—an alloy of which mercury is a principal constituent. Amalgamation may be practised in various ways but they all depend somewhat on the power of gold, in virtue of its specific gravity and metallic character, to separate itself at least partially from its surroundings and by coming into contact with mercury combine with it to form an amalgam. Mercury will not combine with float gold simply because contact is impossible with the elusive little particles whose mass is insufficient to penetrate the surrounding film of water, for amalgamation is invariably performed in a mass of finely crushed ore suspended more or less in water.

In some cases where the gold is relatively fine but not quite at the stage of float gold far less at the colloidal stage, amalgamation is carried out in large iron pans where by the attrition of revolving shoes the surfaces of the particles of gold are being constantly exposed to the mercury which is similarly divided and exposed to facilitate contact. This method necessitates subsequently a long time of settlement for the particles of amalgam and much careful handling in collecting it.

The Mercury must not be regarded as absolutely passive in these operations—the constant attrition, the cutting action of the hard siliceous particles and the chemical action of the metalliferous, sulphurous, and arsenical minerals almost invariably present in gold ores, cause the mercury to "sicken" and to "flour" so that in pan amalgamation the loss of mercury may be serious.

Pan amalgamation is now little used for gold extraction. Indeed, it was originally devised for working silver but, even in its own special department, it is dropping out of use owing to the introduction of superior methods.

But another and simple form of amalgamation is largely practised and indeed is responsible for the production of about one-half of the world's supply of gold, i.e., amalgamation on plates. Briefly described, this method as before requires crushing of the ore in water but instead of being treated in a pan it flows over a sloping table about 8—10 feet long and 4— 5 feet wide.

The table is covered with sheet copper which in turn is covered with mercury which soaks slightly into the copper much the same as butter soaks into bread. In this form the mercury is pasty rather than liquid and as one watches the mass of auriferous sand being carried down the sloping plate by the stream of water he sees one among many rolling particles arrested in its path and after a short pause released to resume its journey—in this moment of arrest the mercury robbed the sand of a minute adhering particle of gold, and having done so allowed its victim to escape, having lost its character as ore and become tailing.

This passage of a stream of water thick with pulverized auriferous rock is continued day after day with short interruptions for cleaning the surface of the amalgamated copper plate and if the ore is rich a little gold amalgam is scraped off occasionally until at the end of the month the crushing is stopped and the "clean up" begins. This is accomplished by scraping the gold amalgam off the plates by a sharp steel

tool resembling a joiner's chisel. The amalgam thus obtained is soft, pasty and like putty in consistence. It is squeezed through bags of chamois leather which allow a fluid mercury to pass through containing only a small proportion of gold and leaving a solid amalgam containing about one-third of its weight of gold and two-thirds quicksilver. The liquid is returned for use and the solid amalgam is packed in an iron retort which is heated to redness by which the mercury is distilled off into water and recovered for re-use, while the gold is left in porous balls about the same size and colour as oranges. This retorted gold is melted in crucibles, cast into ingots and sent in to the Bullion Brokers, who pass it on to the Mint where the refining is completed.

It must be understood that gold in Nature always contains more or less silver. Some Australian gold contains only 1 or 2% of silver. Gold from the Witwaters Rand contains about one-sixth of its weight of silver, and the gold from the North Island of New Zealand generally contains ten or twenty times as much silver as gold, but for convenience I speak of it all as gold.

The Tailings which pass away from the amalgamated plates always contain some gold. If the ore contains the gold originally in coarse particles there is very little left in after amalgamation, but in the average cases where the gold is more or less fine, the loss in tailings is considerable, amounting in many cases to about half of the original contents of the ore. This is much too large a proportion to be neglected but no scheme or process was known for the economical recovery of this gold until the Cyanide Process was invented.

This process depends on the fact that a Cyanide (or Potassium of Sodium) has the power of dissolving gold while its action on the other metalliferous constituent of the ore is so slight as to be in most cases negligible.

The fourth method depends on the fact that a weak solution of Cyanide in water has a selective action on the gold

and devotes most of its chemical energy to the precious metal attacking other constituents, such as iron, sulphur or arsenic, if at all with much less energy. A weak solution is found to be more active than a strong solution, which is fortunate, because cyanide—though comparatively cheap now—is not in the ordinary sense a cheap re-agent, and being dreadfully poisonous the risk is minimised when the solution is weak. The simplest method of applying the solution to the tailing is to allow it to percolate slowly through and to give it one washing of cyanide after another until the major portion of the gold has been extracted. The solution flows away as clear as water and indeed might well be mistaken for water. The lower animals, who are generally good judges of what they should take and what they should avoid, often make the mistake of drinking weak cyanide solution instead of water. Cows are most susceptible to the poison. Mules are not in the least put about by a good drink.

The gold bearing cyanide solution contains only a few grains of gold per ton and the separation of these few grains of gold from a ton of liquid is a chemical and physical problem which requires careful working out. The solution is passed through a mass of finely divided zinc, the zinc goes into solution gradually, and as the zinc dissolves the gold is precipitated on the remaining zinc. The zinc is prepared in a form of thread or wafers and as the gold is deposited in powder the first separation is done by sieving which makes a very thorough separation. The finely divided gold containing the debris of the dissolved zinc may have to be purified by the use of sulphuric acid, or in some similar way, but eventually the gold precipitated in the form of a brownish mud is mixed with flux melted in crucibles and passed on to the Bullion Broker and the Mint as before.

The discovery of new gold fields such as the Witwatersrand, Kalgurli, Klondyke, etc., has stimulated gold production enormously, but the discovery of more economical methods of working has done even more to increase the world's supply so that the production has increased four or five fold within the

last generation, but withal it does not become plentiful for the production of other metals and commodities generally has kept pace so that the ratio of gold to commercial commodities has been little altered.

When gold is taken to the mint it is purified and copper added in the ratio of two to twenty-two of gold so that our gold coinage is 22 carat fine—twenty-four being purity. Twenty-two carat is too soft for use in the arts and 18 carat is about the highest in ordinary use but 9 carat is often used and it looks wonderfully well as compared with brass.

I wish for all of us a better knowledge and closer acquaintance with this metal which is equally wonderful natural or coined.