WONDERS OF WORLD ENGINEERING

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Tin Mines of Malaya

Among the most productive tin mines in the world are those in the Federated Malay States, where the ore is extracted by many different processes, all of them of great interest

THE LONG INCLINE up which excavated material is hauled to the puddlers on the surface. The photograph shows the Hong Fatt Mine, one of the largest open cast mines in the Federated Malay States. The mine is 3,700 feet long, 1,600 feet wide and nearly 300 feet deep.

ALTHOUGH the story of tin is less spectacular than that of gold, it is a fascinating one, particularly to Britons. For it was Cornish tin that put England on the map of the ancient world. In later years the methods of mining in Cornwall and the enterprise and skill of the miners played a great part in the development of mine engineering in other parts of the world.

To-day only a small proportion of the world's tin is supplied by Cornwall. The greater part of the world's requirements is obtained from the Federated Malay States, where enormous mechanical dredges costing up to £100,000 scoop up the tin-bearing earth. A plateau in Nigeria; mines more than 10,000 feet above sea level among the mountains of Bolivia, in South America; and the Netherlands East Indies, Siam, China, Indo-China, the Belgian Congo and other parts of the world contribute supplies of a metal which has many uses. Used as a thin coating to prevent sheets of wrought iron or mild steel from rusting, tin is universally familiar as an essential part of the containers of preserved foods. The British housewife speaks of "tinned" foods, but the American calls them "canned" foods.

There is only the smallest possible amount of tin in the container because the metal is expensive. It is this use of tin that has enabled food canning to develop and bring about enormous changes in the diet of all civilized nations. It has stopped much wastage of food that would rot otherwise and has helped to solve the marketing problem due to the gathering of bountiful crops of perishable fruits. Except for the virtues of tin, millions of tons of food would be wasted or left to rot, large areas would go out of cultivation and the diet of the ordinary man would be far less varied.

Tinned iron is the cheapest and most adaptable metal in which to pack acid foods and it does not taint them or affect them. Although the coat of tin is thin, So huge is the demand for tinplate that much of the world's supply is used in this way. Solders, bronzes, metals for bearings, tinned copper, brass and other metals, type metal, pewter, chemicals, enamel ware and collapsible tubes for toothpaste and other things absorb large quantities of the total output of tin.

The ancients needed tin to harden copper into bronze weapons and implements. Centuries before the Christian era the Phoenicians sailed to Cornwall and bartered Mediterranean wares for tin that had been mined and smelted into ingots. During the centuries that followed the Cornish miners had to go deeper and deeper into the earth in their quest and they achieved some wonderful works of engineering without the aid of machinery.

One great drainage tunnel in a tin mine at Gwennap, made about two centuries ago, drained fifty mines; it was driven through solid rock. In the same century a miner named Thomas Curtis achieved the then remarkable feat of sinking a shaft in Mount's Bay, near Penzance, through rocks that were covered by the sea at high tide. First he built a wooden tower and sunk a pump shaft. Several years elapsed before success came and he won from the workings tin ore worth thousands of pounds. Then a ship broke her moorings during a gale, drifted on to the tower and wrecked it so that the sea poured into the workings and they had to be abandoned. Increased costs of deep mining and the discovery of easily worked deposits of tin ore in the Far East and elsewhere affected the Cornish tin-mining industry adversely.

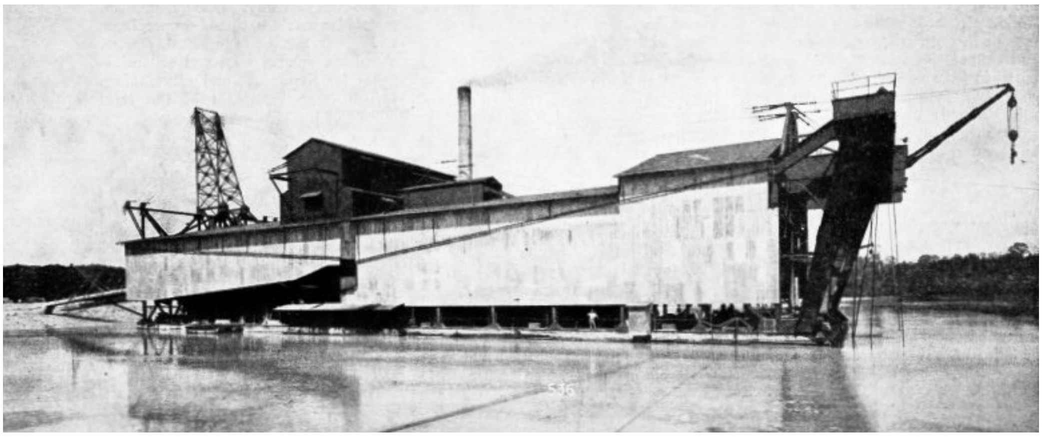
Tin ore is found in many shapes and forms. Erosion of the tin veins in Malaya caused extensive alluvial deposits, and the pitted surface of the limestone formed a trap which retained the grains of mineral. Tin-bearing sand and clay have been affected by subsidences and beds formerly horizontal have been tilted, in some instances to a vertical position. Because of this the prospecting of alluvial deposits that rest on limestone has to be carefully carried out. For example, a bore passing through a vertical layer would appear to yield richly, whereas if the bore had been made only a few yards away it might have missed the rich bed entirely.

The most productive tin-mining area is in Malaya. Almost all the labour is done by Chinese, and the Chinese have been mining tin in the peninsula for centuries. They discovered the rich tinfields of Larut, and various Chinese clans fought one another for possession of these. This led to British intervention in the 'seventies of the last century. Law and order were established, the British introduced rubber trees, the tinfields and lode (or vein) mines were developed by machinery, railways and roads were built and the country prospered in an amazing manner.

Mammoth of the Tinfields

Most of the tin is obtained from alluvial deposits, but not all, for one of the largest lode mines in the world is in Malaya. Prospecting for alluvial deposits is generally done by a hand drill which consists of a steel cutting tool screwed to the end of a string of steel rods. The rods are screwed together and operate inside a 3½-in. diameter steel pipe provided with a cutting shoe. As the casing descends it cuts out a cylinder of earth which is broken up by the cutting tool.

To remove the broken material the rods are withdrawn and, in place of the chisel, a hollow cylinder fitted with a valve is attached. By pressing and turning this against the bottom of the hole it is filled with the broken material. Then it is pulled to the surface, the valve preventing it from escaping, and emptied. In clayey ground a scoop or auger, which will raise the ground besides cutting it, can be used. The ground from the bores is measured and the tin content is ascertained by the processes of washing and assaying. The bucket dredge is the mammoth of the tinfields and has grown in size and power since the first dredge was introduced into Malaya about thirty years ago. An endless chain of manganese steel buckets is carried on rollers resting on a steel ladder, the upper end of which is pivoted on a superstructure some 25 feet to 30 feet above the deck of the pontoon. The lower end of the ladder is suspended by cables which pass to a winch over a top and bottom set of sheaves so that it may be raised or lowered. The buckets pass over tumblers at the upper and lower ends of the ladder. The raising or lowering of the bottom end of the ladder is part of the operation required to bring the buckets to dig into the working face. This must be done frequently when the depth of the tin deposits varies considerably with each slight change in the position of the dredge. Power to drive the bucket line is applied at the upper tumbler through gears.



A LARGE TIN DREDGE used in a Malayan tinfield. The dredge floats in an artificial pond, known as a paddock, which is dug by the dredge as it advances. Water flows into the paddock at the front and escapes at the back. The dredge is moored to the sides of the paddock. An endless chain of buckets brings up the ore and delivers it into a hopper.

The buckets excavate the ground and every cant of the top tumbler delivers a bucket of dirt into the hopper or drop chute, whence it is fed to the revolving or shaking screens. Jets of water break up the dirt and anything unable to pass through the screens travels into the stone chute and is rejected. The tin-bearing material passes through the screens into a distributor which feeds it, with added water, either into jigs or into a series of sluices in which the tin ore is concentrated.

The dredge floats in what is called a paddock, which is an artificial pond dug by the dredge as it progresses. Water flows into the paddock from in front and escapes at the back, carrying with it an amount of slime which varies with the nature of the ground. Ground containing a high proportion of clay is less profitable to work than sandy ground containing an equal amount of tin ore, as the time taken to separate the tin concentrates from clayey soil is longer and the output is therefore less. Dams to retain tailings are built behind the dredge.

In Malaya the usual method of holding the dredge in position is by wire cables. The dredge is pulled up against the working face by a headline. One end of this is attached to a winch on the dredge and the other is anchored on shore, well in front. Sidelines attached to port and starboard enable the dredge to be moved sideways. Dredging practice has made great progress. There are more than 110 dredges in the Federated Malay States.

Steam Dredges Preferred

The capacity of the buckets has been increased to a maximum of 16 cubic feet and the attainable digging depth to over 120 feet. One dredge digs to a maximum of 130 feet below water level. This dredge is 195 feet from the centre of the pivot shaft on the ladder to the centre of the bottom tumbler. The weight of the ladder, ladder rollers, crawler track, crawler rollers and idlers is 622 tons. The lower tumbler weighs 15 tons, and the weight of the buckets, each of which has a capacity of 12 cubic feet, totals 197 tons. The total weight (834 tons) of these items is heavier than the complete weight of a dredge designed to work at shallower depths.

In March 1937 a Dutch dredge called the *Kantoeng*, 3,500 tons, stated to be the world's largest tin dredger, was being towed out to the Netherlands East Indies when she capsized near the Eddystone Lighthouse in a snowstorm. The two tugs were forced to abandon her and the dredge, which was insured for £150,000, drifted ashore near Fowey Harbour, Cornwall. The harbour master, to prevent the danger of the dredge bottling up the harbour, ordered the twenty-two watertight compartments of the pontoon to be holed. This was done and the dredge was scuttled.

At one time the dredges in Malaya were all powered by steam. The fuel was either wood or coal and the main engines were generally of the Marshall horizontal type, a simple and reliable combination. But when steam-electric, diesel-electric and hydro-electric power became available, steam-driven dredge designers improved the steam plant by introducing higher boiler pressures, superheaters and triple-expansion engines. The steam dredge can thus be worked at the same cost as or even less cost than an electrical dredge which obtains its power from an outside source. Seventy-seven of the dredges are operated by self-contained steam plants. Twenty are steam-electric, nine are oil-electric and thirteen are driven by hydro-electric power.

Expensive as is the cost of the equipment, bucket dredges are so efficient that the cost of mining is extremely low and enables ground of low ore content which could not otherwise pay for treatment to be mined at a profit. Every scrap of ground can be excavated where the bedrock is soft, but the bucket dredge is at a disadvantage where the bedrock is uneven and the tin oxide is lodged in channels and crevices.

Gravel pump mining is popular with the Chinese miners. A pressure pump feeds monitors, or nozzles, and the powerful jets of water disintegrate the ground. The broken material is washed along a channel in the bottom of the mine to a sump. The next stage is to lift the mixture of sand, clay and water by the gravel pump to the head of a flume, called a *palong*, which may be from 40 feet to 120 feet higher than the sump.

ELECTRIC EXCAVATOR at work in a Malayan open cast tin mine. The excavator, or navvy, is of the Ruston Bucyrus type. Excavated material is loaded into trucks and hauled up inclines to the surface, as shown in the photograph at the top of this page.

Stops or wooden bars are placed at intervals along the bottom of the flume to retain the heavy tin ore. Most of the lighter sand and clay passes through the flume with the stream of water to the dumping ground. As the process continues the height of the stops is increased by the placing of more wooden bars on top of the others across the bottom of the flume. When these have reached the maximum height the flow of water and sand is either cut off or diverted into a flume running parallel.

The mixture of tin ore and sand in the flume is further concentrated by raking it against a flow of water. Water is introduced at the head of the flume and the clean-up continues until the flume is empty. The concentrates are placed into wooden buckets and taken to the washing sheds for final treatment. The water required generally exceeds the normal supply, and therefore the overflow from the tailings dam is led into a reservoir to supplement the normal supply.

A few mines are worked by pumps on a pontoon. Two pumps and the machinery for driving them are installed on the pontoon. One of the pumps is for supplying water to the monitors and the other for lifting the resulting sand, gravel and water. The water from the monitors cuts away the ground and the gravel pump lifts it to the sluice, where the ore is concentrated. To move the pontoon the paddock is filled with water so that the pontoon floats and can be shifted to another site. The disadvantage of this method of mining is that if much water seeps into the mine it causes expense for pumping, and the method has been largely displaced by bucket dredging.

Another method is by hydraulicking, using water under natural head. The first step is to build a dam across the bed of a stream at an elevation which will produce the necessary volume and pressure of water. The water is carried by pipes or by ditch line to a pressure box, and then by pipes to the mine, the pressure depending upon the height of the pressure box above the mine. The jet, which emerges from a monitor, is directed against the face of the mine into which it cuts. The mixture flows down a ditch or a wooden sluice. The tin ore is partly concentrated by the flow of water, and the concentration is continued by women using a round, shallow wooden dish called a *dulang*.

The *dulang* has a diameter of about 30 in. and is about 33, in. deep in the centre. The dish is placed in the stream and sand and water are put into it. By a peculiar motion the woman washes the waste matter over the edge of the dish, retaining the ore. The work is hard, as the women working in streams labour with bent backs in the heat of the tropical day.

When the ground to be worked lies below the drainage level of the district or lacks sufficient gradient, elevators are used. These raise the disintegrated ground and water to a higher level and enable the necessary slope to be given to the sluice. A jet of water, under pressure, sucks in water and gravel and forces the mixture up a pipe to the sluicehead.

Sometimes there is used a combination of hydraulicking with water under natural head and gravel pumps to act as elevators. At one mine the first 300 feet of fall develop electrical power, and the remainder supplies water under pressure to the mine. The variation in the equipment of such mines is great. It ranges from installations using only 100 cubic feet a minute under a pressure of 50 lb. per square inch to big pipe lines carrying 6,000 cubic feet of water a minute and producing a pressure of 170 lb. per square inch. Diameters of nozzles vary from 1 in. to 3 in. Large monitors cut the ground rapidly, as a 3-in. nozzle working under a pressure of 170 lb. per square inch has potential energy of about 340 horse-power at the nozzle.

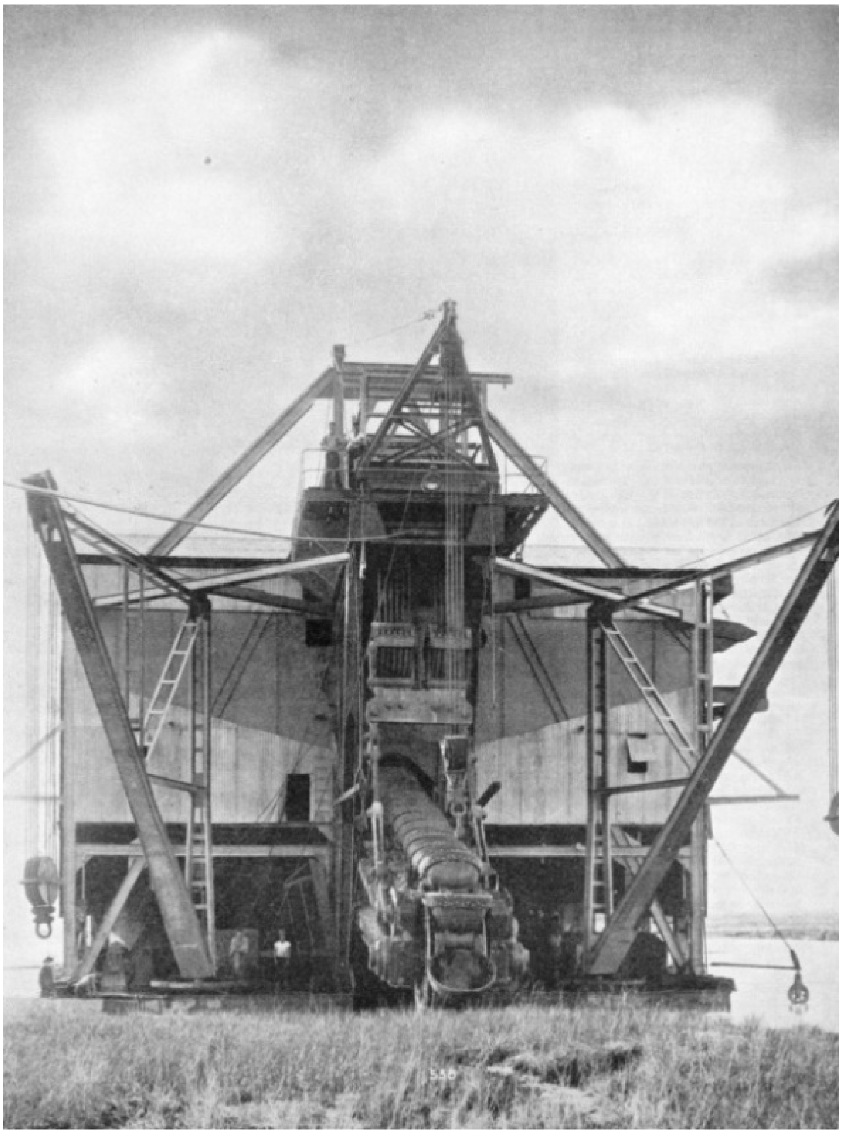
"Lampan" Working

Hydraulicking with water not under pressure is called “lampan” working. The water is led along a ditch at the foot of the mine face. Then men cut the face into steps, starting at the top and working downwards. When they reach the bottom they begin to work upwards, cutting the steps away so that the material falls into the ditch, where much of the sand is washed away by the water, leaving a concentrate. This is cleaned to extract the tin ore. Another method is to lead the water over the face of the mine from the top so that it helps to break up the ground.

Huge quantities of tailings are produced by hydraulicking and these have caused great trouble in the past, especially in hilly districts. Earthworks are built to impound the tailings, with masonry spillways to release flood water.

Large excavations have been made by open cast mining with trucks and rails. The old Sungei Besi Mine, which was cut by Chinese using a kind of hoe, is 3,000 feet long, 1,200 feet wide and about 120 feet deep. The more recent mine opened to the north of the earlier one is being excavated by an electric navvy. In these mines the material is loaded into small trucks which are run over light rails and are hauled by electric power up an incline to the surface, where the contents are dumped into puddlers. After having been stirred, the pulp is passed to jigs, where it i? subjected to a pulsating action which concentrates the tin ore and allows the sands and slimes to flow to the tailings flume.

THE ENDLESS CHAIN OF BUCKETS in a modern tin mine dredge. The buckets are made of manganese steel and have a capacity of about 16 cubic feet. They dredge to a maximum depth of about 120 feet. The chain of buckets is carried on rollers resting on a steel frame or ladder which is pivoted to the superstructure at the top and suspended at the bottom by cables leading through sheaves to a winch. Thus.the lower end of the chain of buckets can be raised or lowered as required. The men standing on the deck of the pontoon give an indication of the size of the dredge.



Hong Fatt Mine is larger than the others. It is 3,700 feet long, 1,600 feet wide and nearly 300 feet deep. Four electric navvies excavate on the upper benches and hand labour is still employed at the bottom. The broken ground is loaded into small trucks and hauled up to puddlers, but instead of being treated by jigs it is passed over sluices where the ore is concentrated.

In most open cast mines the tin-bearing sand is under overburden which is sometimes- 60 feet deep. This has first to be removed and dumped well out of the way. The faces of the mine are worked in a series of benches, separated by sloped faces. Lines of rails run along the benches to the different haulage inclines; one set leads to the puddling and dressing plant and the other set to the overburden dump.

Before the introduction of giant navvies and power pumps the ingenious, hard-working Chinese solved the problems in their own way, but open cast mining by hand is disappearing.

Where this method survives the ground is put into two flat baskets suspended from the ends of a pole. The coolie balances the pole on his shoulder and mounts a log laid at an angle and notched in the form of steps. Removal of water was formerly effected by a chain pump made of wood. Boards set at right angles to a wooden chain were fitted in a wooden trough, the base of which was in the sump and the upper end placed high enough to enable the water to flow away. The chain was revolved either by treadmill or by waterwheel.

The tin-bearing material is first puddled by hand in a square pit, and then carried to the cleaning sluices, coffin-shaped boxes called landchutes. Water is led into the head of the box, and the material is shovelled in by a coolie at the side. Another coolie stands in the water, raking the concentrates with a kind of hoe called a *changkol*. Other men or women dig out the waste material and carry it away.

Where the tin-bearing material occurred as a thin bed under a much greater thickness of overburden the alluvial shafting method of mining was used, but this has largely been abandoned because of its wastefulness.

Some shafts are 200 feet deep, some are circular pits large enough to allow the coolie to squat at the bottom, and others are double compartment shafts timbered from top to bottom. In shallow workings the method is to sink shafts about 30 feet apart to reach the ore and then to remove the whole bed, the roof of the excavation being supported by timbers between the shaft bottoms. Water is removed by buckets and a winch, or by a pulsometer pump. Artificial ventilation is rarely used, and then only in the form of a windchute. Old workings of this type are often exposed in the faces of open cast and gravel pump mines. The richest ground has been removed, but what remains yields good profits to modern methods of mining.

The lode mines of the Pahang Consolidated Company are among the largest producers of tin ore in the world. They are at Sungei Lembing, in the north-east of the State of Pahang, in the watershed of the Kuantan River, about twenty-six miles from the east coast. A daily river service is maintained by the company between Kuantan, the port, and Pasir Kemudi, a distance of twenty-eight miles. A light railway, fifteen miles long, links Pasir Kemudi with the mine.

Originally these lode mines were worked by Chinese, but Europeans began mining in 1887 and have worked them continuously since. The lodes are in hilly country ranging from 120 feet to 1,150 feet high. The outcrops of most lodes have been worked by the open cut system.

Ore Lodes 1,200 Feet Deep

Several lodes have been worked below adit level to depths of about 500 feet, and in the Willinks and Myah Mines a series of ore lodes has been opened down to a depth of 1,200 feet and for a distance of over one and a half miles along the strike. These lodes have been worked to 1,000 feet above adit level. Lodes vary in width from a few inches to 60 feet. Electric battery locomotives are used for transport underground.

Ore is treated in a central mill, where the battery consists of fifty head of Californian stamps and four head of Holman air-cushion stamps. Before being crushed, the ore is washed on shaking screens, then reduced by jaw-crushers and conveyed to the stamp battery bins. The pulp is classified into three products, the coarse being distributed to jigs, the sands to sand tables and the slimes to slime tables.

The “heads” from all are then calcined in a roasting furnace, the “middlings” go to pans for regrinding and reclassifying, and the tailings are rejected. The roasted concentrates are ground in pans, and after classification are passed over retreatment tables. The products are treated on the dressing floor, and the tin ore is dried and bagged for shipment to the smelters at Singapore.

The central power station at Sungei Lembing, near the Willinks Mine, consists of six diesel engine generating sets totalling 4,900 horse-power. There are also eight steam boilers totalling 1,515 horse-power. Most of the power is used for pumping water from the mines. Three air compressors supply the underground hoists and rock drills. The mechanical and electrical workshops are so complete that the mines are almost independent of outside engineering concerns.

OPEN CAST MINE in the State of Selangor, Malaya. The mine is excavated in a series of benches along which rails are laid to convey the truckloads of excavated material to the inclines which lead to the surface, where the tin-bearing ore is extracted and treated.

Power for mining varies according to circumstances. The loco-portable steam boiler fired by wood cut from the jungle is used in open cast mines in remote districts. The diesel engine is used extensively in gravel pump mines. Some companies use a number of engines of from 200 to 300 horse-power in preference to one large engine with a standby. Mines in the Kinta Valley obtain power from the 27,000-kilowatts station, at Chenderoh, of the Perak River Hydro-Electric Power Company. Many mines use the power of the Kuala Lumpur supply system. The coal used in power stations and by steam-driven dredges is mined at Batu Arang, in Selangor, and is called Rawang coal. It is rather soft and friable but gives good results.

At one time smelting was done by Chinese in the principal mining districts, but there is now only one Chinese smelter, in Kuala Lumpur, where the old type of blast furnace with charcoal as fuel is in operation side by side with a small blast furnace of European design.

Almost the entire tin output of Malaya, Siam and Burma is smelted by two companies which operate in Penang and Singapore and deal also with ore from South Africa, Australia, Indo-China, Japan and North America. The tin is afterwards shipped, principally to the United States. These two plants have oil-fired reverberatory furnaces. As a considerable amount of the tin is volatilized during smelting a fume-recovery plant is installed to save tin that would otherwise escape with the furnace gases.

The ore is mixed with limestone and anthracite - the limestone as a flux for the gangue (worthless) minerals, the anthracite as a reducing agent for the tin dioxide. Molten tin is tapped from the furnaces at intervals, and when the charge is completely smelted the molten slag is run off and a fresh charge is dropped in. The first slag, known as ore slag, contains enough tin to warrant resmelting. From this a final slag is obtained and discarded.

100-lb. Ingots

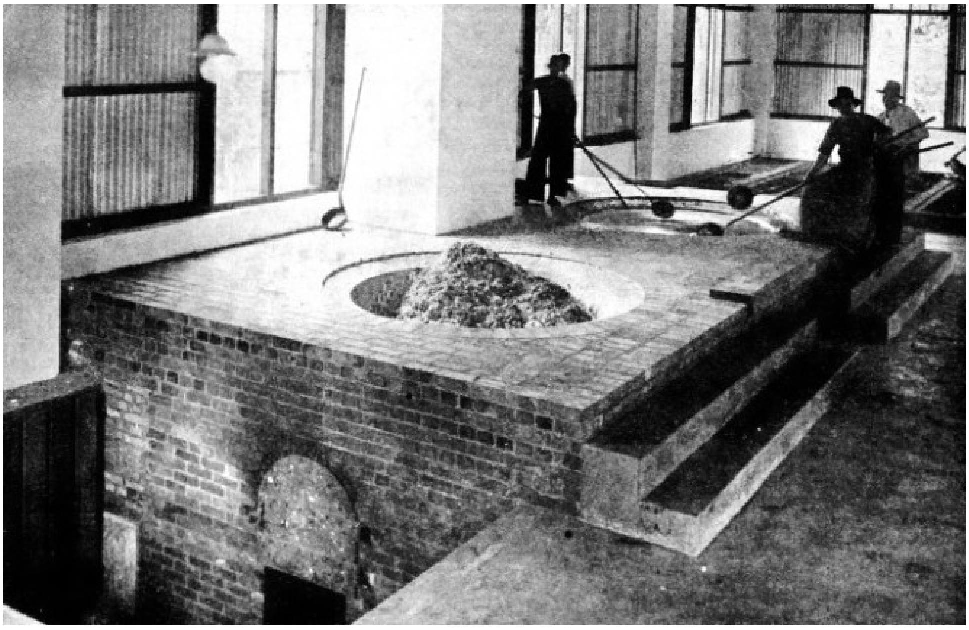
The molten tin is refined in cast-iron kettles by agitation. A dross containing most of the impurities forms on the surface and is skimmed off at intervals. The refined tin is allowed to settle and is kept at a temperature just above melting point. After refining the tin is cast into 100-lb. ingots. Ores which contain arsenic and sulphur are roasted before treatment at a temperature which drives off the arsenic and sulphur but does not cause the ore to fuse.

Bolivia is assessed next to Malaya in the quantity of tin produced. The Bolivian mines are high up in the mountains at altitudes ranging from 11,000 feet to 16,000 feet, and the town of Oruro, which is a railway junction and the centre of a large tin-mining district, is 12,100 feet above sea level. Potosi, at 13,600 feet, is higher still. La Paz and Chorolque are other tin-mining districts of Bolivia.

The rapid rise of Nigeria as a producer of tin is remarkable. The metal was mined in small quantities for centuries and was taken across the desert to ports on the Mediterranean and to the west coast, where it was bartered in thin rods.

There was considerable mystery as to the origin of this tin until the late Sir William Wallace found, while opening up the River Benue for trade in 1884, that the tin was produced in Northern Nigeria on the Bauchi Plateau. Eighteen years later he was sent as Political Agent with a British force which subdued the Emir of Bauchi, and he sent out emissaries who secured a small quantity of tin sands.

Wallace took the sand back to England and showed it to the directors of the Niger Company. Prospecting parties were sent out and eventually the considerable mining industry was. developed and railways were built.



REFINING PANS in the Chinese smelting plant at Kuala Lumpur, Malaya. The tin is smelted in these pans and the slag, which rises to the surface, is skimmed off with ladles. The skimmings can be seen in the pan in the foreground. This is the only Chinese smelter left in Malaya, the rest of the tin being smelted by two European companies.

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