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THE ROMANCE OF TIN*

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PEOPLE usually associate tin with tin cans—prosaic objects perhaps unworthy of a romantic theme. This is because the word " tin " lost caste about three centuries ago when it was misappropriated by those who were trying to sell cheap tinplate ware, a competitor of the more expensive pewter (Hedges 1960). But tin yields only to gold and copper as the earliest metal known to man (Singer et al. 1958) and was first reduced from ores by smelting in the neolithic age about five thousand years ago (Hoover and Hoover 1912a), though smelting was only fully established in about 1600 B.C. and probably began in North West Persia (Aitchison 1960).

It is no use looking for native tin, since not sufficient has so far been recovered in all the world's tinfields to plate a sheet large enough to make one sardine-tin (Jones 1925). If an early barbarian had attempted to put out or bank his fire with handfuls of black alluvial sand—in reality tinstone or cassiterite—he would find to his surprise next morning particles of a bright shiny new metal, and this may account for the few grains of metallic tin that have been reported.

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Cornish inhabitants used brushwood and turf as their only fuel, going to a considerable depth after peat, and digging into the moors which once contained an abundance of cassiterite. Successive floods then washed valuable deposits which accumulated in brooks and rivers, giving the high-quality stream tin (Watson 1843).

Bronzes

Our knowledge of prehistoric tin comes from our knowledge of prehistoric bronzes. Copper had been used from time immemorial for weapons; but, although fairly easy to obtain, by itself it is soft, and the alloy with tin made bronze, which was very much stronger, and easy to cast in a mould. When less than 3% of tin was present, the bronze was probably accidental, since the tin could have its origin in the impurity of the copper ore used. When there was much more than 3% the mixture must have been made by design. There is no need to add pure metallic tin to copper: the smelting of bright green, blue, or red ores of copper with black tinstone may have led to the discovery of bronze before the discovery of tin.

The four Rivers of Paradise are the Indus, Tigris, Euphrates, and Nile. The earliest recorded bronzes, containing up to 20% of tin (Desch 1931), date from about 3500–3000 B.C. and were found at the royal cemetery at Ur near the mouth of the Euphrates, one of these four rivers. They were made by the people of Sumer who developed the first great civilisation of a modern type and who

Fig. 1—Map of Old World.

supplied ideas to Egypt, while Syria, Libya and Sinai supplied raw materials (Frankfort 1951).

The early bronze age in Egypt began about 3500 B.C.; but, since there was no tin in Egypt, possible sources are shown with arrows (fig. 1).† The spread of knowledge of the alloy to Egypt almost certainly came from Mesopotamia through Palestine, or through Southern Greece via the Aegean islands and then Crete (Hall 1928). Some tin went to Egypt from Britain, particularly in the 5th century B.C. (Forbes 1950), though it was not until the 6th century A.D. that ships from Alexandria visited regularly with cargoes of grain which they sold, half the value being paid for in gold and half in tin (Partington 1935). This is the date when John the Almsgiver tells us that an Alexandrian seaman sailed to Britain with corn, relieved a famine, and returned with a cargo of tin which was miraculously changed to silver on the way (Jenkin 1927).

The term " age " has only a limited application in the history of metals. The " bronze age " does not have fixed and identical dates in all countries, just as an " atomic age " may now come to some countries more quickly than to others. It began in Egypt nearly a thousand years before Northern Greece, but in Great Britain it was between 1800 and 1600 B.C. (Piggott 1963) and there seems no doubt that the knowledge of bronze came to this country from abroad.

It is likely that bronze art was discovered independently in different continents, and that so was tin. There is no evidence that knowledge of bronze was imported to Mexico and Peru; and, though at one time bronze was thought to have been introduced into China, recent excavations suggest that the Shang bronze industry developed in the very heart of China centuries before the establishment of the Shang capital at An Yang, in 1384 B.C. (Cheng Te K'un 1960).

Tin was known to Homer between 900 and 750 B.C. as κασσίτερος and in the *Iliad* we learn that Agamemnon's shield had 20 knobs of tin making a circle around the dark enamel boss.

Sources of Tin

Cornwall

The exact site of the Kassiterides (" whence comes the tin we use ", says Herodotus) can now hardly matter, but it has been the subject of tremendous argument and scholastic research—for example, Smith (1863). Since the only important island source of ancient tin was Britain, the name Kassiterides must surely refer to Britain generally and to Cornwall, and perhaps also by mistake to the Scilly islands where tin may have been exchanged. Probably tin was being mined in Cornwall long before the Phœnicians (Partington 1935), perhaps paying for imports of amber (Clark 1948); and there is nothing to prove Camden's unhappy guess in 1722 that the Phœnicians not only traded with Cornwall but even mined the tin (Hencken 1932). The myth of the Phœnicians and Cornish tin has been perpetuated ever since the 18th century, as by Borlase (1769).

The first account of tin in Britain comes from the first Greek to reach Britain—Pytheas, in about 325 B.C. He was from Marseilles or Massilia, a town founded by refugee Ionian Greeks, and it was probably his lost account of this voyage which is used by Diodorus Siculus and Strabo at about the time of Christ (Holmes 1907). It was a blockade-running voyage, for the Phœnicians were in control of the Straits of Gibraltar from towards the end of the 6th century B.C. until the Roman conquest of 206 B.C. (Clark 1952). Tin was conveyed by the people of Lands End in wagons at low tide from the British mainland to an island called Ictis; purchased there by merchants from the natives; carried to Gaul; and transported on pack-horses to the mouth of the river Rhone, the overland journey lasting thirty days. Tin was sometimes taken to Ictis, best identified as St. Michael's Mount, in " little wicker boats covered with leather ". Probably the French port was Corbilo at the mouth of the Loire, known to be destroyed by Julius Cæsar in 56 B.C. (Bromehead 1947).

Strabo tells us that the Phœnicians were thought to have a monopoly of the tin trade, and when the Romans followed a certain shipmaster that they might find the market, the shipmaster purposely ran his vessel upon a shoal, leading those who followed him into the same destructive disaster. He himself escaped by means of a fragment of the ship, and received from the State the value of the cargo he had lost.

Cornish tin entered international trade about 500 B.C. This continued until Cæsar's time, when it diminished under competition from Spain and Portugal. The Romans revived it about A.D. 250, after the Spanish mines became exhausted, and it retained its supremacy until the 19th century (Aitchison 1960).

Other Ancient Sources

I have considered Cornwall in this detail because it supplied much of the world for so many hundreds of years, and because tin mining was of such importance in Bronze Age Europe (Forbes 1963). It even supplied a murderer who discovered tin in Germany in 1241 (Hoover and Hoover 1912b). There were at least four other ancient sources however: Europe, the Far East, Africa, and South America.

Europe.—Most of the easily won ores of the Near East had been exhausted by about 2000 B.C., after which the bulk came from Bohemia and Saxony at first. Under Roman occupation Spain and Portugal acquired almost a monopoly of the production of tin, and the mines were well known to Pliny in A.D. 79. But they failed about A.D. 250 and perhaps this led to underestimation of their importance (Borlase 1874, 1897). Near the tin district of Monte-Rey, near Orense, is the haunted lake of Limia, about which the strange tale was told that the swarms of gnats which hovered around its shores were the enchanted army of King Arthur of Britain. In 1551 Molina wrote:

> " Our realms hath tin produced,
> So plenteous in the Vale of Montey-Rey,
> The metal white, of quality so rare,
> Not even England's purest can compare
> With that which holds the mart in each Medina's fair."
> (*Quoted by* W. C. BORLASE, 1897.)

The Far East.—The second ancient source is the central plain of China. After centuries of experimenting, the Shang Chinese invented a very efficient crucible for their bronze craft and made both single-mould castings and multi-mould castings with internal cores. The early Shang bronzes (containing 15–20% tin) are of a different composition from Western ones (10% tin) (Watson 1962). They date from about 2100–1750 B.C. and in the late Shang period of 1400–1100 B.C. (Cheng Te K'un 1960) the industry reached its height with complicated objects of which fig. 2 is an example. These Chinese Yunnan deposits are now thought to be part of a vast Asian metallogenic tin province: that is, an area where primary tin

† The lectures were illustrated by a film and many slides, only a few of which are reproduced here.

deposits were formed at the same period of mineralisation (Jones 1925). This extended down from China through Burma and Thailand and Malaya to Bangka and Billiton off Sumatra (fig. 3). The Chinese traded with these parts, though the earliest record of a voyage between the near East and China seems to be that of an Arab named Abu Dulaf about A.D. 940. Both he, and others in the 12th and 13th centuries (Idrisi, A.D. 1154 and Ibn Sa'id, A.D. 1210–1280), are all agreed that there was a most important trading centre and watering-place on the way between India and China at Kalah, which contained a tin mine within the city walls. It was even noted that merchants adulterated the pure metal after its extraction from this mine (Idrisi, quoted by Wheatley 1961).

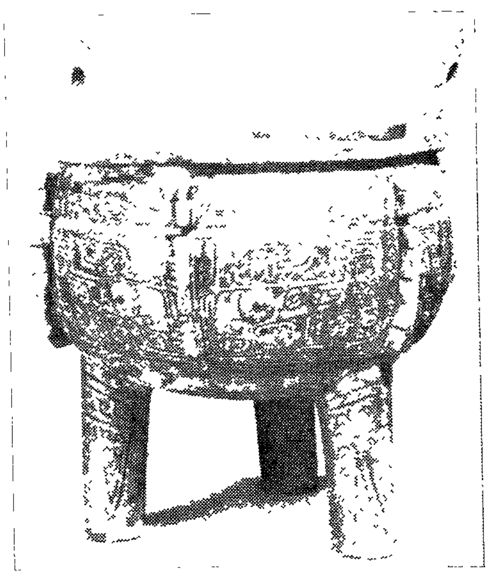

Fig. 2—Bronze cauldron, Shang Yen Period.

(Reproduced by permission of the Syndics of the Fitzwilliam Museum, Cambridge.)

Although Kalah seems to occupy the same uncertainty as the Kassiterides in its exact location, Wheatley suggests that it was in the Mergui district of Burma, near the Thailand border. That region is well known for its rich alluvial deposits of cassiterite, and further south—at Tongkah near Puket island in Thailand, for example—even the harbour and main street have been dredged for tin (Jones 1925). During the Portuguese period of the 15th and 16th century there was a big trade in Malayan tin which attracted Indian vessels to Malacca, and at this time Mercator tells us that large tin coins were in circulation in Sumatra (Beckmann 1846).

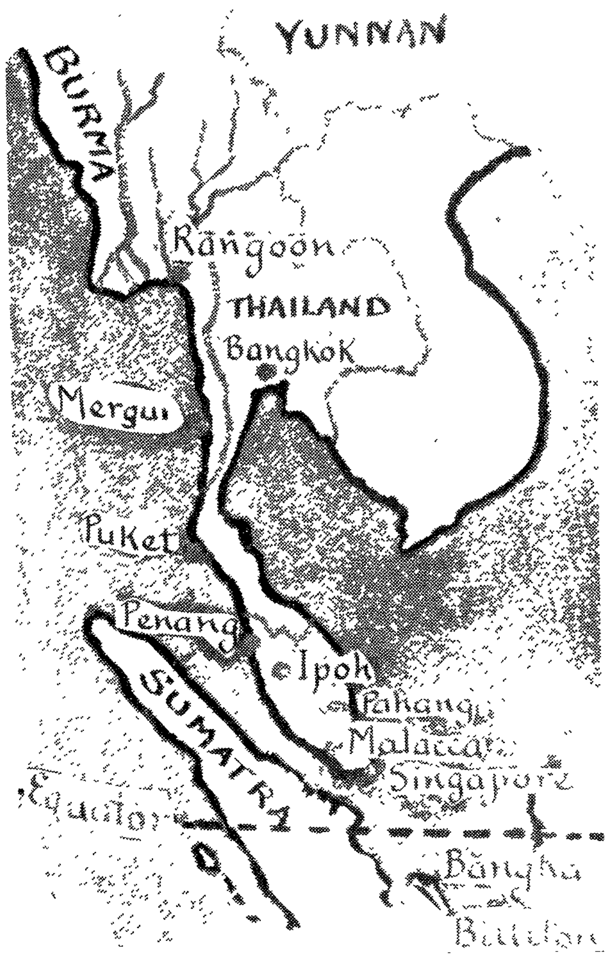

Fig. 3—Map of Malaysia.

The history of the Malay peninsula is built up around efforts, through the centuries, of Western countries to get its trade, especially in tin. After large-scale Chinese immigration began in 1850, the Chinese tin communities soon were quite unable to keep the peace between themselves. In 1873 H.M. Government intervened " to rescue, if possible, those fertile and productive countries from the ruin that must befall them if the present disorders continue unchecked."

At this time, when Chinese fighting and Malay lack of control were usual in tin communities (Tregonning 1962), tin production was about 7000 tons per year. By the 1880s it averaged 20,000 and by the 1890s, after the discovery of the Kinta Valley, near Ipoh, it averaged over 40,000 tons a year (International Tin Study Group 1954).

Fig. 4—Underground mining at Corinth, about 550 B.C.

The collapse of the European mining boom by 1885 gave a wonderful opportunity to Chinese miners to buy mines and machinery cheaply (Gullick 1955). It was British protection, undertaken essentially because of the tin trade, that created some stability in Malaya and let the Chinese immigrate to become labourers in mines and rubber estates, fishermen and domestic servants, and, in the second and later generations, merchants and professional men (Winstedt 1935).

Africa.—Unlikely though it is, one is tempted to think that both copper and tin reached ancient Egypt from the interior of Africa, since tin ores occur in Nigeria and the Belgian Congo, with small amounts in Southern Rhodesia and the Union of South Africa. Bernard Fagg (1963) in his museum at Jos, has some preliminary evidence that tin was known in Nigeria as early as the Nok culture of two thousand years ago, and he has found both palæolithic and neolithic implements in the alluvial tin deposits of the Bauchi plateau (Fagg 1946), where Sir William Wallace found in 1884 that the natives were producing metallic tin.

South America.—In Mexico and Peru at the time of Cortez (A.D. 1520) bronze contained 6% of tin; and even in the centuries before the Incas, copper was mined and used for practical and decorative purposes. When the Spanish came in the early 16th century, cruelty, greed and intolerance going hand in hand with the lust for gold and silver, they regarded tin as a waste-product of silver ores, which they found being mined already at Potosi in 1544. Lazarus Ercker's treatise of 1580 discusses at length how to separate silver from tin, and there are enterprises in Bolivia today engaged in extracting tin from the tailings of Colonial silver mines. At the end of the 19th century Patino's discovery of the famous mountain of tin at Catavi began an era in which tin has accounted for about 80% of Bolivia's mineral exports.

Mining Methods

Since stannite (Cu_2S, FeS, SnS_2) is rarely used, the only important mineral that is a source of tin is cassiterite (SnO_2), which if pure, contains 78·75% Sn, and is found only near to granite. It occurs either in lodes underground, or as alluvial or eluvial deposits on the surface; and this difference is reflected in the different methods of mining the ore, of concentrating it, and of smelting it, and in the medical hazards that arise because of these differences.

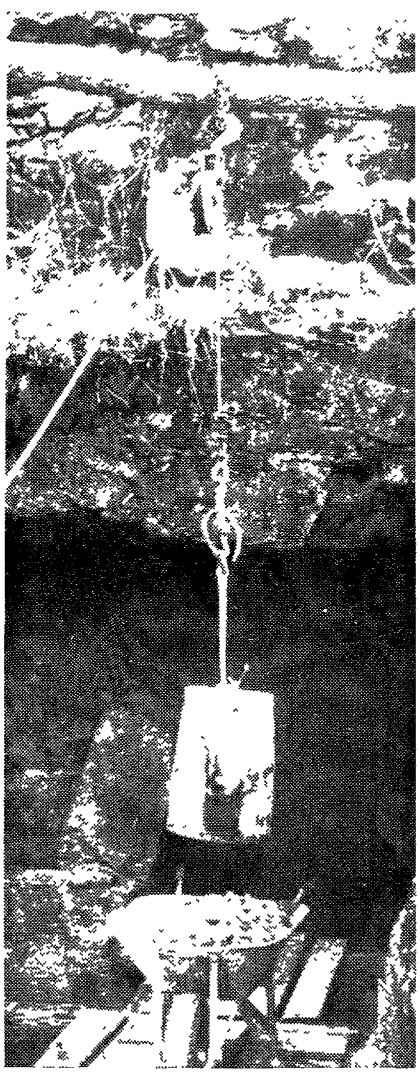

Fig. 5—Small lode mine, Northern Queensland.

Lode Mining

Underground mining of minerals has been practised since well before Christ, as may be seen from this picture from Corinth of about 550 B.C. (fig. 4). There is the miner, his assistant, the miner's light, and the muck clearers.

Lode mining for tin involves getting out of the ground a layer of rock containing enough cassiterite to pay the expenses of the mine, and still make a profit. The proportion of tin in terms of metallic tin (Sn) needs to be as much above 1% as possible; but only in rare small lodes does it reach 10% or more.

The mine may begin as an adit, or cutting into the hillside, which later tunnels into the rock. Later still it may be reached by a shaft, and many such small mines are still to be found (fig. 5) looking very like Agricola's picture of 1556 (fig. 6). As the years have gone by, the shafts have got deeper, and whereas 300 ft. was very deep in the 15th century, 3000 ft. is not so remarkable today when pithead gear and cages are used. As recently as 1841 in Cornwall, the Loam man-engine was the first to save the men the trouble of climbing up and down 1000 ft. or more (Jenkin 1927).

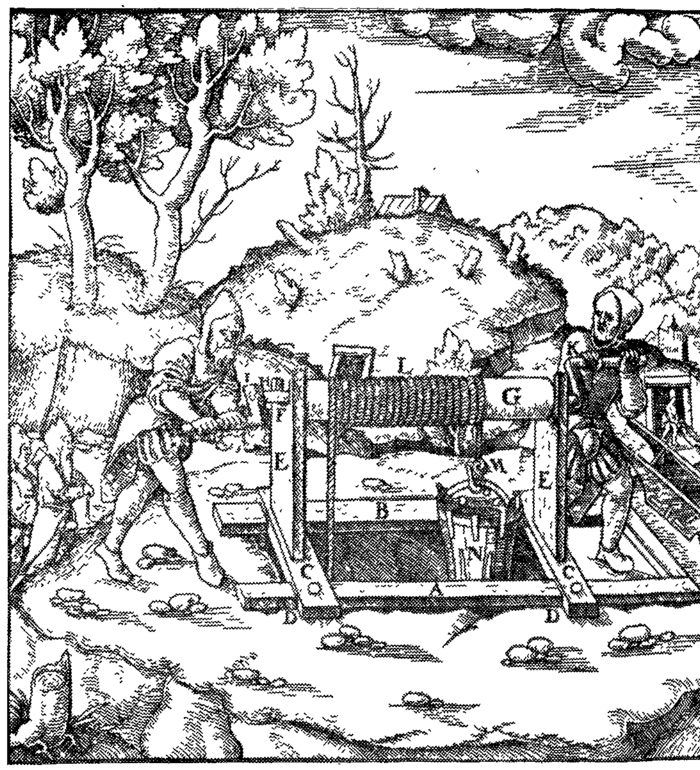

Fig. 6—Small lode mine: Agricola, 1556.

The Engine by which he is raised from below
Now supersedes climbing, health's deadliest foe.
This miners know well and their gratitude show,
Their core being ore. From labour they cease
And delighted avail them, O LOAM of the ease
Thy genius procured them, and joyful ride
On the rod, while others descend by their side.

This rhyme, which appeared with contemporary illustrations, suggested that it was climbing and not silicosis that caused the dyspnœa. The beam went up and down and men jumped off on to the sollars or static platforms, at the side. But you do not always have to go *down* mines, and in Bolivia you tend to go *in* or *up* a mine. Once in the mine, you may be in a narrow shaft, or in a tunnel needing replacement of pit props (fig. 7), or in a tunnel in which fungus is growing, or in which the colour of the minerals such as copper is very evident.

Then the rock has to be broken at the working face. This is done by blasting, and compressed-air drills are used nowadays to make holes for the insertion of the explosive. Whether we have a Czech driller in Cornwall

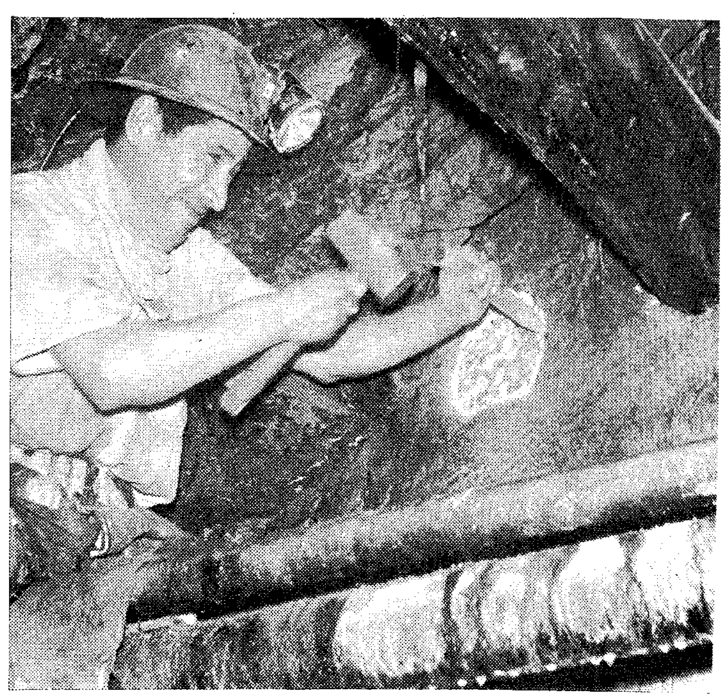

Fig. 7—Replacement of pit prop, Bolivia.

(fig. 8) (watched by Dr. L. W. Hale, who has written an excellent account of tin mining), or an Australian in Tasmania, or a coca-chewing Bolivian in South America, does not make much difference. In all cases water is supposed to be used to reduce the widow-making activities of the drill, since the lode is usually associated with quartz. I have tried dry drilling in Bolivia: it is far less messy because water does not splash back into your face, the particles of respirable-sized silica are not visible, and there is no smell or taste. It is easy to see why even now many men won't bother to use the water all the time.

To one brought up in this country, where explosions in mines usually mean entombment and death, it is psychologically quite uncomfortable to hear the tremendous noise of drilling, with just a dim source of light at the bottom of a slope, to hear the blasting underground, to feel the granite rock shake, and to see someone calmly lighting a cigarette. And, of course, you should not have claustrophobia.

Fig. 8—Dr. L. W. Hale watching a Czech driller in Cornwall.

After an explosion, the tunnels are filled with smoke and dust, and the rock face should not be visited for some time—a rule which can be enforced only where mine discipline is good. It varies from a matter of minutes in Bolivia to hours in Cornwall and Tasmania. If there are large lumps of rock they may need a further explosive charge to make them conveniently small. Then the broken rock is taken to a shaft called a boxhole, where it can fall down a shute. The rock finally reaches a convenient level where it goes in trucks by train to the cage and thence up to the surface. Once outside the mine, the trucks tip their cargo on to a grizzly, and the lumps of rock are taken through the mill, which is nearly always on a hillside to let gravity help.

Sometimes there is hand selection to remove the rubbish, but generally the rock just goes through to the primary crusher. There is no reason why this should not be wet (apart from the difficulty of a water-supply), but silica dust obviously can arise here. The rock is first reduced in size to about $2^1/_2$ in., and then is pulverised. The principle of concentration depends largely on the specific gravity of the cassiterite, which is heavier than the minerals with which it is mixed. Sometimes there is a "sink and float" mechanism in which the crushed ore is poured into a fluid of a specific gravity such that the tinstone will sink and other minerals will float.

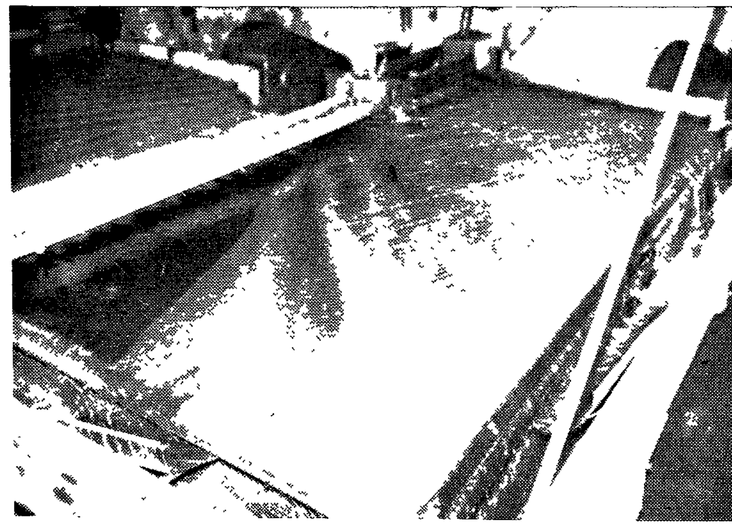

Fig. 9—Concentrating table, Bolivia.

Next we have vibrating screens of different meshes; but sometimes only jigs are used, in which a pulsating jet of water forces upward the lighter material, while the heavier tinstone sinks and is collected on the jig. Since there are penalties at the smelting-works for impurities such as

Fig. 10—Alluvial mining: Agricola, 1556.

sulphides, these may be floated with a bubble-forming agent, and then wiped off with revolving blades.

The last stage is the most important in understanding why those handling these concentrates can get pneumoconiosis due to tin dioxide but not due to silica. The concentrating tables (fig. 9) slope downwards both lengthways and sideways; they shake, and are fed from the top left-hand corner (Williams 1957). Heavy material such as tin travels to the left, but the lighter particles—including all the 5 μ silica—are swept away by water to the right and so are not available to produce silicosis when the dried concentrate is handled later. Commercially it is not a good method of saving the 5 μ cassiterite, even though this is much heavier than the silica; but some is in fact saved, as we know from electron-microscope studies, and experiments with rats. There is silica in the lode ore concentrates, but only in combination with cassiterite in large particles which cannot cause a pneumoconiosis.

The tin is then dried, and usually it is possible to send a concentrate containing up to 60% Sn to the smelter after bagging by hand into bags weighing 70 to 100 lb.

Alluvial Mining

In alluvial mining the process is quite different. In rare instances, at the beginning of the discovery of commercially important deposits, the " black sand " had only to be shovelled up. More frequently it has had to be collected behind some barrier to the flow of water, as Agricola shows (fig. 10), in which the lighter particles flow over the top, but the heavier ones sink. The procedure is carried out on the tailings in Bolivia, and on the Jos plateau of Nigeria natives can still be found damming part of a river and then digging out the heavy mud. The project may be more ambitious, as when the ground is dug deeply, the heavy mud is carried on the heads of women labourers, and is then hand washed in a calabash. The large round shallow dish-like container is swirled so that water carries away the lighter minerals, leaving the tinstone as a concentrate, the weight of the pan and its contents being supported by the water in which the panning is done. It is the most efficient method known, has been practised for centuries, is extremely cheap, and is used by small mine-owners, though for large volumes and poor-quality ground more modern methods are adopted.

In hydraulicking, the tin-bearing material is either washed by a powerful jet of water directed at the face of the mine, or else it is dragged out and piled up in a convenient heap, later to be washed by a monitor. The resultant mud is pumped up by a gravel pump, passed through a grizzly, and then falls gently down the slope of the sluice-box (fig. 11). The heavy tin ore collects behind the wooden slats or riffles running athwart the sluice-box, and can be dug out, just as it was four hundred years ago.

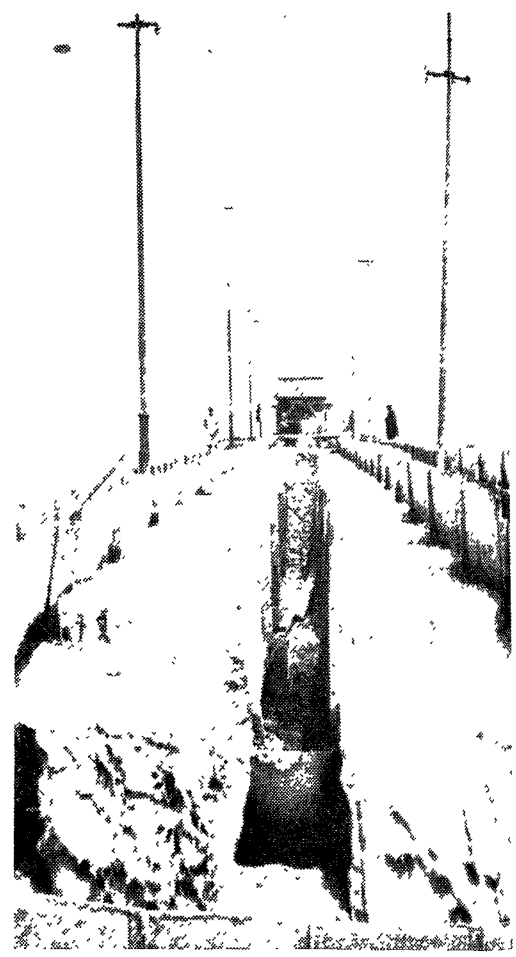

Fig. 11—Sluice-box, Jos, Nigeria.

Finally, alluvial material may be removed with the dredge, a gigantic pontoon which may weigh nearly 3000 tons, in use in Malaysia, and also in Australia from which it was first brought (fig. 12). The buckets are from 5 to 15 c. ft. mounted on an endless steel chain, and each weighs up to about $1^1/_2$ tons and picks up about a ton of material. They make an unforgettable screaming sound as they slowly revolve over the pulleys at the top of the dredge, tipping their contents into a hopper. From here the mud passes into a downward sloping revolving screen, in which the tin ore and material less than about $^3/_8$ in. in size is first washed free and then goes to sluice-boxes and screens and jigs. Anything larger—stones, pieces of timber, or large lumps of clay—is discharged by a shute over the stern. The tailings, which are separated into water and mud, are sprayed some distance from the stern of the dredge, and are used to build up a bank or fill in a pond behind the dredge. The cassiterite content may be as low as 8 oz. per cubic yard, and yet the enormous volume dealt with—perhaps 2 million cubic yards a year—can make the operation profitable. The buckets can remove a dry overburden as well as scoop out the wet tin-bearing material, in which case dry sand goes off the stern, and the dredge goes from side to side across its pond—an artificial one formed by the dredge. The buckets can be lowered or raised, and may be dredging as deep as 170 feet or more. It is not very efficient where there is a limestone bedrock with pinnacles, between which rich patches of ore might remain inaccessible.

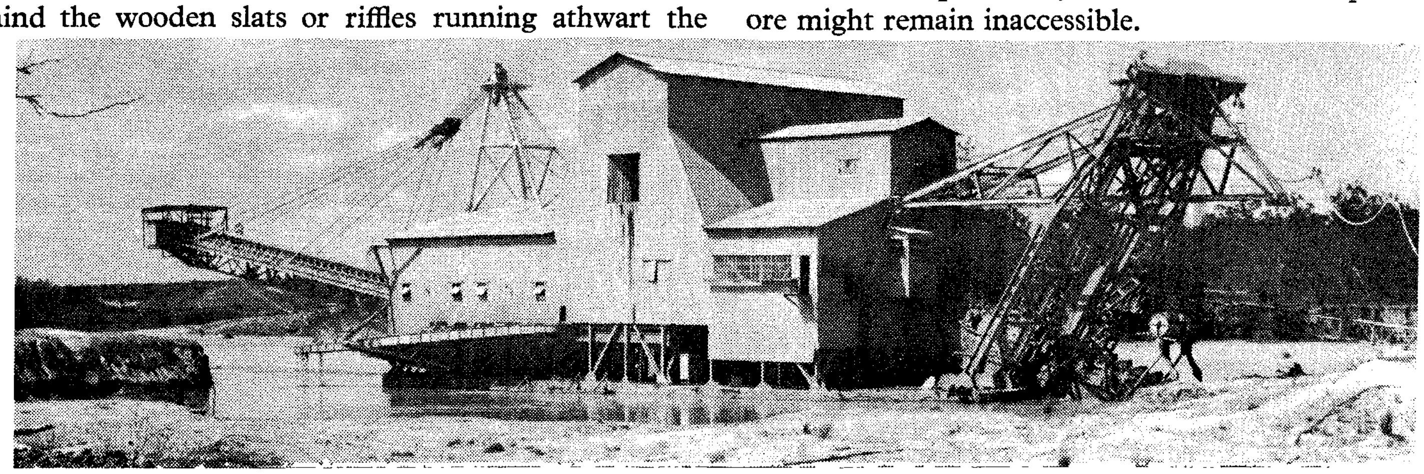

Fig. 12—Dredge, Northern Queensland.

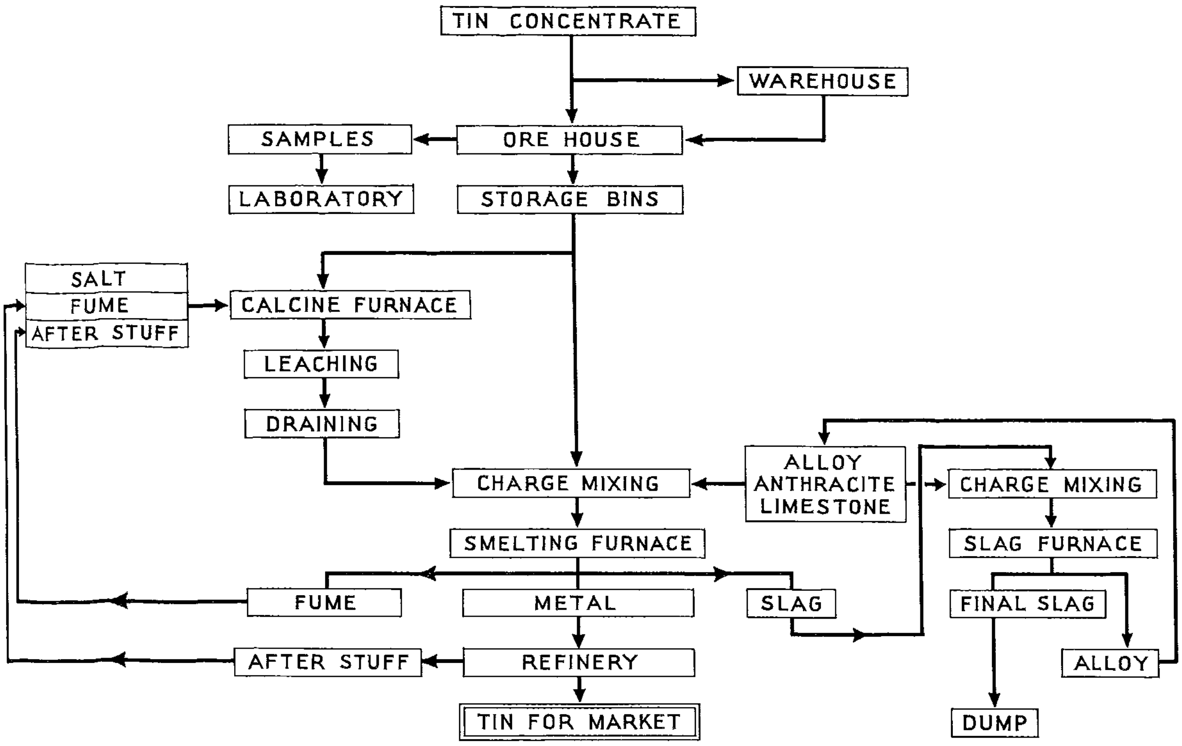

Fig. 13—Flow sheet of a typical smelter.

The mill for dealing with alluvial ore, initially concentrated either on the dredge or on the long sluice-box, is usually much simpler than for lode ore, and entails virtually no grinding. Electromagnetic separation is used to remove the iron so frequently found, and a good concentrate will end up with about 75% tin. Like the lode concentrate, it is bagged and sent to the smelter.

The methods of obtaining concentrates from alluvial sources have all involved sluice-boxes of some kind, and these will not retain particles of 5 μ. All mining engineers I have spoken to are emphatic on this point. It is, of course, the reason why manual handling of tin concentrates from alluvial sources never gives any pneumoconiosis, either from tin dioxide or indeed from silica.

Smelting

The metal tin can only be obtained by smelting tin ore. One of the earliest smelters known was that found at Chun Castle in Cornwall, dating from the 2nd or 3rd century B.C. Tylecote (1962) gives a suggested reconstruction of this installation, and thinks that the ore was intimately mixed with charcoal in a bowl, with a horizontal flue to admit the air and a vertical flue to take away the exhausted gases. Gowland (1899) suggested that the early furnaces were merely narrow shallow trenches in the ground, lined with clay and filled with brushwood, above which small logs of wood were piled. As soon as the logs were burning fiercely and the trench was full of glowing embers, small quantities of ore would be thrown on from time to time, and the molten tin would accumulate in the trenches and perhaps flow into a small cavity at one end of the trench. As with most ancient refining methods, a metal of surprisingly high purity could be won, but with heavy loss of metal in the slag, and in the case of tin, by volatilisation (Singer et al. 1958). The first clear exposition of tin smelting is to be found in Agricola's *De Re Metallica*. It seems that, in general, tin did not see the mechanical and metallurgical development of other metals until the 20th century.

The modern process of tin smelting is best understood with the aid of a cine film (Robertson 1960a), and the flow sheet (fig. 13) of a typical smelter is an incomplete substitute for the film.

In the smelter in Liverpool, concentrates which are handled are lode from Bolivia and alluvial from Nigeria. This means that it is often a long time before material dug from the earth is converted to tin, and so there is a complicated method of payment to the miners, which must depend on careful assays. Bags of concentrates weighing 70–100 lb. are manually emptied into skips, where samples of a tenth of each bag are automatically taken. The man on the skip may handle 1000 of these bags each day, and so is exposed to much dust. The samples are later hand-ground, sieved, and machine-ground, before being assayed by the tin smelter and by a representative of the tin mines, so that a proper price may be agreed.

In calcining, the ore concentrate is roasted with salt at about 600°C, and the hot ore is discharged into water to leach out the soluble impurities. The roasted product is then mixed with anthracite and smelted, the reaction in simplified form being

$$SnO_2 + C \longrightarrow Sn + Co_2$$

This takes place at about 1500°C, and causes losses of tin in the furnace gases. These are filtered by Dracco bags and the " fume " is resmelted.

Studies in Liverpool

Investigation of the whole process by history-taking from over 200 employees, by observation and photography of the various jobs in the works, and by correlation with the radiographic findings, showed those places where dust concentration was likely to be especially high (Robertson and Whitaker 1955). Samples have been taken with a Hexlet by Dr. S. A. Roach of the London School of Hygiene, and analysis of the tin content and the total ash confirmed the initial impressions. Table I shows quantities of dust in various places throughout the works, though these are preliminary figures, and our full survey will be published later. There is a quite satisfactory dose-response curve in terms of milligramme-years with the radiographic categories.

Some lung-function studies (forced expiratory volume and airways resistance) by Dr. Gilson of the Pneumoconiosis Research Unit have shown that there is no disability, whatever the radiographic category (Gilson 1960).

This study began in 1952, and at that time the litera-

TABLE I—DUST CONCENTRATION IN mg. per 100 cubic metres

Occupation	Tin	Ash
Check sampling shed	222	419
Dracco	150	275
Smelting furnace man	155	224
Refining furnace man	82	144
Orehouse skipman	34	143
Plumber	12	21
Electrician	5	19
Engineer	2	7

TABLE II—WORLD DISTRIBUTIONS OF STANNOSIS

Authors	Year	Country	Patients
Beintker	1944	Germany	1
Pendergrass and Pryde	1948	U.S.A.	1
Bartak, Tomecka, and Tomicek	1948	Czechoslovakia	7
Cutter, Faller, Stocklen, and Wilson	1949	U.S.A.	2
Dundon and Hughes	1950	U.S.A.	1
Spencer and Wycoff	1954	U.S.A.	1
Robertson and Whitaker	1955	England	121
Schuler, Cruz, Guijon, Maturana, and Valenzuela	1958	Chile	10
Robertson, Rivers, Nagelschmidt, and Duncumb	1961	Bolivia	10
Picken and Scott	1961	Malaya	12

ture contained 12 cases, but none from England. It is now more extensive, and stannosis has been described in South America and in Malaya as well as in large numbers in Liverpool (table II).

The dust, collected by Hexlet to pick up only material less than 5 μ in diameter, has been investigated by electron microscopy and animal experiments (Robertson 1960a). Full analysis of the lungs of seven patients (Robertson, Rivers, Nagelschmidt, and Duncumb 1961) included a new method of identifying a particle as small as 1 μ in a phagocyte. These various investigations all provide evidence that many workers at the Bootle smelter had a deposition of the highly radio-opaque tin dioxide rather than fibrosis. It is known that the radio-opacity of lesions depends on a power of the atomic weight of the element concerned, and so tin (atomic weight = 118) will show up very readily. If any of us living for years in an industrial area have 1 g. of harmless carbon in our lungs, it will not show on the radiograph, whereas 1 g. of harmless tin dioxide would show up.

Long-term Hazard?

It is important to know whether there is any long-term hazard in the process of tin smelting. There were two fortunate circumstances in trying to assess this. One was that there were records of all the men employed since the firm moved from Cornwall to Liverpool in about 1910. The other was that many of the employees had long service, and there was a tradition of father and son and even grandson at the works. Figures are now available for the mortality from all causes, as well as certain specific causes, in England and Wales in quinquennial periods from 1921 onwards, for groups of men of all ages (McKenzie et al. 1957). These were compared with the population at risk at the works, and we chose those with a minimum period of three years' employment there, since no patients had developed radiological evidence of stannosis under this period of time. There was no other qualification.

640 men were included in this field survey, and of these about 5% could not be traced. The actual deaths were

TABLE III—TOTAL DEATHS IN TIN-SMELTING FIRM, 1921–55

Employees	Actual	Expected deaths (U.K.)	Expected deaths (Bootle)
Untraced	33	(6) } 172	} 204
Dead	131	166 }	
Alive	476	..	..
Total	640	..	..

131, in comparison with an expected 166 *without* the 33 untraced, or 172 *with* the 33 untraced. (That is, of the 33 men who could not be found, 6 would be expected to die during the survey period.) (Table III.) There is a Merseyside factor which makes for an increased mortality for those living on Merseyside. If this is introduced, as it should be, the 172 expected deaths rise to 204. Thus our population at the works has shown less mortality than expected.

A few diseases were calculated separately. Tuberculosis was 8 actual compared with 14 expected (or 23 with the Merseyside factor). Cancer was 30 actual compared with 28 expected or 34 with the Merseyside factor. There were a few bronchial cancers. Those who had no risk of pneumoconiosis were slightly more likely to get bronchial cancer than those who had an especial exposure to fume or dust.

Full details of this inquiry, which began in 1954, will be published in due course. I have had the good fortune to have the statistics checked by Dr. Richard Doll of the Medical Research Council, to whom I am grateful for many hours of help.

(*To be concluded*)

TREATMENT OF CHRONIC TENSION HEADACHE

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THE occasional mild tension headache which is relieved by aspirin is a common experience. When such headaches recur frequently, "all day and every day", for ten, twenty, or thirty years, they become a major therapeutic problem.

A constant factor in the production of tension headache appears to be inability of the patient to relax the muscles of the face, scalp, and neck. Patients are often told by their friends that they frown and look worried, although they may not be aware of it. The majority of patients are apt to clench the jaws firmly, and some state that they have noticed their jaws clenched and fingers flexed tightly in a fist even on awakening from sleep. When they are being examined they are unable to relax the jaw muscles so that the jaw can be moved freely by the physician. They are unable to let the head loll back when the shoulders are supported since the neck muscles remain rigid. They cannot permit their elevated arm to fall limply to the couch when requested by the examiner to do so. An interesting feature about this "over-contraction" of muscle is that it is not limited to a time of emotional crisis but continues when the patient has no real problems. Many patients say that they have not got a care in the world except for their headache. Others may experience persistent symptoms of anxiety or mild depression. Some patients may have an underlying abnormality of the bite which increases the tendency to jaw-clenching (Berlin and Dessner 1960).

Not every person who is a chronic frowner suffers from headache, which denotes that other factors are involved in the production of pain. One of these is constriction of the blood-vessels supplying the scalp muscles (Tunis and Wolff 1954). Brazil and Friedman (1956) reported that nicotinic acid 100 mg. relieved tension headache completely in 45% of patients, and partly in 33%, when given as a single dose while the headache was present. Ostfeld et al. (1957) have shown that vasoconstriction can be seen