THE RELATIONSHIP OF THE GEOLOGICAL SURVEY TO THE MINING INDUSTRY OF MALAYA

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British Malaya is a peninsula extending southwards from the southernmost boundary of Siam and it is more or less equal in size to England, having a total area of 51,076 sq. miles. West of it lie the Straits of Malacca, separating it from the large island of Sumatra, while the east coast is washed by the China Sea. The island of Penang is situated in the north, off the west coast, and the island of Singapore is in the south, at the toe of the peninsula. Naming the States from north to south, Malaya includes Kedah and Perlis, Penang, Province Wellesley, Perak, Kelantan, Trengganu, Pahang, Selangor, Negri Sembilan, Malacca, Johore and Singapore.

Malaya has a tropical climate with heavy rainfall. Certain parts have been developed by mining and agriculture, and there roads and railways have been built, but it is a fact not appreciated even by many who have spent all their lives in the country that more than three-quarters of the Peninsula is still covered with jungle and is uninhabited. Much of the unknown part is mountainous. The positions and heights of the chief mountains have been surveyed by the Trigonometrical Branch of the Surveys Department and a considerable part of the country has been mapped by the Topographical Branch.

The highest mountains of Malaya are over 7,000 ft. and there are many peaks more than 6,000 ft. high. The country is well watered, and before the British came in, less than one hundred years ago, to build roads and railways, rivers provided the chief means of access inland. Much of the coastline is fringed by broad plains, more or less at sea-level, built by the rivers depositing their loads of sand and silt at their mouths, and so continually building the plains further and further out to sea. We geologists often use the rivers for our journeys. There is little geological information to be gathered where they pass through the coastal plains, and only small craft can be used up-river where rapids become frequent. Here the geologist and his coolies have to do a lot of wading, pulling

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their dug-outs over the rocks. So long as they can progress a few miles in a day, this is the best way of getting stores inland, but eventually a stage is reached where they have to abandon this method of transport. When the geologist has reached the area he wants to examine, he makes a depot by putting most of his stores high up in a tree, beyond the reach of marauding elephants, and with a dozen carriers, Malays or aborigines, he makes side excursions on foot, taking canvas sheets for shelters and enough food for six or eight days, after which he plans to be back at the depot again to renew stores and start exploring in a new direction. Probably he intends to return to civilisation by a different route, examining new country as he goes, so he crosses the watershed to the headwaters of another river, which he follows downstream, and when the stream is big enough he and his coolies build a bamboo raft to carry them down-river. He stops for a few nights at selected places to climb the neighbouring mountains and examine the country in detail.

Under my predecessor, Mr. J. B. Scrivenor, the Geological Survey Department made a reconnaissance geological survey of the Peninsula and reports were published on part of Pahang, on the Kinta Tinfield, on Perak, Selangor, Negri Sembilan, Kedah and Perlis, Johore, the Langkawi Islands (west of the Perlis coast), Singapore, Malacca, and also short accounts on Trengganu and Kelantan. A summary of what was then known of the geology and mineral deposits of Malaya is contained in Mr. Scrivenor's two books, *The Geology of Malayan Ore-deposits* and *The Geology of Malaya*. Latterly, we have been engaged on detailed surveys, and reports on three areas in Perak and Pahang have been published, with four geological maps in colour, based on topographical sheets of scale 1 in. to 1 mile, covering about 1,100 sq. miles. Within three years from now it is expected to have reports ready for publication on six additional areas, illustrated by a further twenty maps of the same type, covering about 6,000 sq. miles. But for the Japanese invasion these would already have been published.

**THE MINING INDUSTRY OF MALAYA**

*Tin*

Any description of the Mining Industry of Malaya must be devoted mainly to tin mining. Exports of metallic tin from the Federated Malay States, not counting those from the Unfederated States, from the year 1900 to the time of the Japanese invasion at the end of 1941, amounted to more than two million tons, representing nearly 40 per cent. of the world's output.

In 1939, while restriction was in force to keep unwanted supplies off the market, the tinfields of the Federated Malay States were allowed to produce 52,232 tons of metallic tin, 28·3 per cent. of the world's output. In 1940, when it was necessary to get large stocks, and restriction was in some measure abated, the production
rose to 81,332 tons, amounting to 34·3 per cent. of the world’s output; in the first six months of 1941, 41,585 tons were produced.

While the Japanese were in occupation of Malaya, from February, 1942, to August, 1945, they worked some of the tin mines, and information collected from the Japanese mining officials now interned in Singapore indicates that they produced between 12,000 and 15,000 tons of metallic tin. Thus, in 3½ years, their total output amounted to what was being produced every two months during 1940 and 1941.

The Mitsui Mining Company, with its head office in Ipoh, Perak, controlled 25 dredges near Batu Gajah, Malim Nawar, Kampar and Bidor, and four hydraulic mines, but eight of these dredges were never operated. Another Japanese company also worked mines at Gopeng, Malim Nawar and Kampar. Still another company had three dredges working in North Selangor at Kalumpang and Rasa, beginning in September, 1943. The Ishihara Sangyo Koshi, a company that had long owned iron mines in Malaya, was responsible for getting eight dredges going in South Selangor, opening up in April, 1943, but they experienced great difficulty in keeping them going and they mined only 440 tons. The same company had one dredge working in South Johore from October 1944 to July 1945 to produce 128 tons of tin. The total production of metallic tin from the State of Pahang during the Japanese occupation was about 200 tons.

Other Minerals

Coal was first mined in 1915, and from that year until the end of 1941 about ten million tons were won, all for local use. The Mitsubishi Mining Company had charge of the Batu Arang Colliery (in the Tertiary of Selangor) during the Japanese occupation, from February 1942 until August 1945, and it is said that they mined 30,000 tons a month.

In the last 50 years 800,000 oz., of gold have been mined.

Iron ore, most of it high grade, was mined in Malaya by the Japanese for about 20 years before 1941 with gradually increasing outputs, and during their last six years of operations they were exporting to Japan at the rate of more than 1½ million tons a year. They did not work the iron mines at all during the years they occupied the country.

The Japanese began to mine bauxite (aluminium ore) in Johore in 1936, and in 1938 exports to Japan were more than 55,000 tons. According to figures supplied in December 1945 by the Senior Engineer of the Ishihara Sangyo Koshi interned in Singapore, 370,000 tons of bauxite were shipped during the 3½ years of Japanese control in Malaya, and this included 120,000 tons from a deposit in Malacca that had not been touched prior to 1942; but we know that, from causes outside their control, much of that 370,000 tons did not reach Japan.
Exports to Japan of manganese ore from two mines in Kelantan and Trengganu for the six years before the invasion were about 30,000 tons a year.

The tungsten ores, wolfram and scheelite, were produced at the rate of hundreds of tons for many years, and while the famous scheelite mine at Kramat Pulai was in production the hundreds became thousands.

Malaya also possesses extensive deposits of kaolin (china-clay), which, however, is mined only in quantity sufficient for local needs.

Ilmenite is a by-product of alluvial tin mining in North Malaya, and there are about 300,000 tons of it collected in dumps in the tinfields; only a few thousand tons have been exported each year. It is used in the manufacture of the important white pigment known as titanium-white.

Thousands of tons of zircon also could be obtained from dumps in the tinfields, and a limited quantity of monazite would also be available.

It is unlikely that mineral oil will ever be found in Malaya in quantities worth producing.

It is not possible to give the exact value of the two million tons of tin produced since 1900, but it was somewhere between £400,000,000 and £500,000,000, whereas the value of all the other minerals mined during the same period might have been as much as £50,000,000, not more. Clearly tin mining is the main mining industry of Malaya. Moreover, when tin mining is spoken of in this paper, except when lode mining is specifically referred to, mining by alluvial methods is implied, because by far the greater part of Malaya's tin production—more than 95 per cent.—is from loose deposits of sand and clay. Nevertheless, it is to be noted that one of the most important lode tin mines in the world, that operated by the Pahang Consolidated Company, Limited, is situated in Malaya.

**Geological Structure and Tin Deposits**

A geological map of British Malaya shows that the different rock formations occur as elongated outcrops, roughly parallel with one another and with the length of the Peninsula. This arrangement came about as a result of folding movements which crumpled rock layers into a succession of parallel waves that were later eaten into by erosion. Granite masses occupying anticlinal cores have been laid bare, flanked by the upturned eroded edges of the various metamorphosed strata that formerly overlay them.

Some parts of these granite masses and the metamorphosed rocks near them contained veins of tin ore, the erosion of which has led to the accumulation of alluvial tin deposits. The fact that the veins were all located near the periphery of a granite intrusion
determined that alluvial deposits also are sited near granite contacts, and this does indeed apply to all the principal tinfields of Malaya. Bedrock under the Kinta tinfield and the Kuala Lumpur tinfield consists mainly of crystalline limestone, with pitted surfaces that formed very efficient traps for holding back the heavy grains of tin ore as they were borne over them by streams. In fact, the surface-irregularities in these plains behaved like riffles on the surface of great concentration-tables. Deep solution-troughs are located along lines of contact of limestone with less soluble rocks, such as granite or schist or quartzite, and, where the contact-rocks were mineralised, such troughs contain the richest deposits of detrital tin ore.

**Modes of Occurrence of Tin Ore**

The only tin ore of any importance in Malaya is the mineral cassiterite, tin dioxide, SnO₂. Its colour in Malaya commonly is brown-black, of a distinctly lighter shade than the cassiterite of Cornwall. Sometimes, indeed, it is pale brown, and occasionally a white variety is found. Rarely one finds specimens of green or red cassiterite. Sometimes it is found as large crystals, but usually it occurs as sand, in various grain-sizes, from pieces the size of a pea down to the finest flour. It is a heavy, hard mineral that can withstand a great deal of abrasion.

Tin ore usually occurs in layers of detrital gravel with quartz pebbles and white clay, underlying other alluvial beds which may or may not also contain tin ore. Tin ore is also found in solid rock, in stringers and veins, in granite, schist, limestone, and quartzite. It is repeated that the richest deposits are found near the contact of granite with limestone and other rocks. Having found the tin deposits, the problem that confronts miners is to find the best method of excavating them and of separating tin ore from the impurities which constitute more than 99 per cent. of their bulk. When they have isolated the tin ore, they sell it to the smelting companies, who produce metallic tin from it.

**MINING METHODS USED IN MALAYA**

Tin mining methods now practised in Malaya may be classified as follows:

- **Dredging**
- **Gravel-pump mining**
- **Hydraulicking**
  - (a) using water under natural head
  - (b) with water not under pressure
- **Open-cast mining**
  - (a) with trucks and rails
  - (b) by hand labour only
- **Lode mining**
Dredging

The bucket dredge used in Malaya is of the endless chain type. A continuous 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 to 30 ft. 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 as required to bring the buckets to dig into the working face.

The ground is excavated and delivered into the hopper or drop chute, whence it is fed to revolving or shaking screens. Jets of water break it up, and anything unable to pass through the screens travels into the "stone chute" and is rejected. 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 a pond dug by itself as it progresses. Water flows in at the front and escapes at the back carrying slimes with it. Dams are built behind to retain tailings.

Dredging has proved most successful in Malaya, and much ground of low value which would otherwise have been left untouched is being worked profitably. Where the bedrock is soft, the whole of the tin-bearing ground can be excavated, but losses occur when the bedrock consists of limestone pinnacles, because the richest material is contained in inaccessible channels and hollows. In 1941 there were 123 dredges operating in Malaya with a total designed dredging capacity of about 22 million cu. yds. a month. In 1940 they produced ore containing 42,204 tons of metallic tin, more than half of Malaya's total output. In the first six months of 1941 they produced 21,297 tons.

Gravel-pump Mining

The method of mining most popular with the present-day Chinese in Malaya is by gravel-pump. Usually a pressure-pump is used to feed monitors which throw jets of water powerful enough to cut and disintegrate the ground. The broken material is washed along a channel in the bottom of the mine to a sump, whence the mixture of sand, clay and water is lifted by a gravel-pump to the head of a palong or flume, which may be anything from 40 ft. to 120 ft. above the sump.

The heavy tin ore is held up at numerous points along the length of the palong by stops, or wooden bars, placed one on top of the other at intervals across the bottom of the flume. Most of the lighter sand and clay passes out of the palong with the stream of water, to be deposited in the allotted dumping space. After several days, when the stops in the palong have been raised to a certain height, the supply of water and sand from the gravel-pump is shut off, and the mixture of tin ore and sand in the flume is
further concentrated by raking it against a flow of water. The concentrates from this operation, containing about 50 to 60 per cent. of tin dioxide, are placed in wooden buckets and taken to the washing sheds for final treatment.

**Hydraulicking using Water under Natural Head**

In this method a dam is constructed in a stream bed at such a height in the hills as may be necessary to produce the required pressure at the level of the mine. The impounded water is then conveyed either by pipes direct to the mine, or in a ditch-line to a pressure-box whence it flows down pipes. There it emerges under pressure from a monitor which resembles the nozzle of a fire-hose. The jet is directed at the face of the mine, cuts it down, and the resulting mixture flows down a ditch or a wooden sluice in which the tin ore is partly concentrated by the flow of water, and women are employed to continue the concentration by using a round, shallow, wooden dish called a *dulang*. In cases where the ground to be worked lies below the drainage level of the district, or lacks sufficient grade, elevators are used to raise the disintegrated ground and water to a higher level from which the necessary slope can be given to the sluice. A jet of water under pressure sucks in water and gravel and forces them up a pipe, delivering them at the sluice-head.

**Hydraulicking with Water not under Pressure**

Hydraulicking with water not under pressure is known locally as *lampan* mining. Water is led along a ditch at the foot of the mine face, which is then cut into steps by men who work downwards, starting from the top. When the bottom of the face is reached they work upwards, cutting the steps away. The ground so removed falls into the ditch, where much of the sand is washed away by the water and a concentrate remains from which the tin ore is extracted. A variation of the method is to lead the water over the top of the face using it as an agent for breaking up the ground.

**Open-cast Mines with Trucks and Rails**

Some enormous excavations have been made by mining with trucks and rails, as in the Sungei Besi District of Selangor. In 1938 the Hong Fatt Mine had an area at the surface of 116 acres, and at the bottom of the mine, which is 310 ft. below road level, 3½ acres. From this huge hole, 30 million cu. yds. of earth had been removed. Four electric navvies were used on the upper benches, but hand labour was employed at the mine bottom. The broken ground was loaded into small trucks and hauled up to puddlers, whence it was passed over sluices where the ore was concentrated.

**Open-cast Mining by Hand Labour only**

Open-cast mining by hand labour is a purely Chinese method.
The ground is put into flat baskets which are hung at either end of a carrying stick carried on the shoulders of the coolies. They climb up gently-inclined, notched logs that serve as ladders from the floor to the top of the mine.

The karang, or "pay-dirt," is first puddled by hand in a square pit and then carried to coffin-shaped cleaning sluices. Water is let into the head, and the karang is shovelled in by a coolie at the side. Another coolie stands in the water raking the concentrates with a changkol, a kind of hoe, while other labourers, men or women, dig out the waste material and carry it away.

Until recently, open-cast mines were de-watered either by a primitive wooden chain-pump or by portable steam engine or oil engine operating a centrifugal pump, but lately electricity has been replacing other forms of power. Electric power is supplied in Perak by the Perak Hydro-Electric Power Company, Limited, and, in Selangor, by the Government-owned Kuala Lumpur Power Station.

**Lode Mining**

The mines operated by the Pahang Consolidated Company, Limited, combine to form one of the biggest producers of tin ore in the world. They are situated at Sungai Lembing in the Kuantan district in north-east Pahang, near a small outcrop of granite. The lodes are located within an area approximately 6 miles north and south by 2½ miles east and west, in hilly country ranging from 120 ft. to 1,150 ft. above sea-level. Prospecting has located no important alluvial deposits, although, as is usual, the lodes were discovered originally by prospectors following up alluvial ore in the creeks.

The tin-bearing lodes radiate from the eastern side of a granite intrusion into the overlying shale, schist, quartzite and sandstone; some occur also in the granite itself. They strike east and west, and they dip either north or south. The pitch of the ore-shoots in the lodes is roughly parallel to the contact of the granite with the schist.

The ore-bodies have no well-defined walls, and consist generally of narrow fissures filled with mineralised quartz, with varying widths of impregnated country rock on either side. In some cases the ore-body is a stockwork. In addition to cassiterite, the lodes carry iron pyrites, zinc blende, copper pyrites and arsenical pyrites. No wolfram occurs in the lodes and tourmaline is uncommon.

Owing to the hilly nature of the terrain much mining has been possible above adit level, and the outcrops of most lodes have been worked by open-cut. Several lodes have been worked below adit level to depths of about 500 ft., and, in the Willinks and Myah Mines, a series of ore-bodies has been worked to a depth of 1,200 ft. below adit and for nearly two miles along their strike. These same