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THE MODERNISATION OF JAPANESE NON-FERROUS METAL MINING*

——A Survey of the First Phase 1868–1885——

by

Norikazu Kudo

Abstract

The development of non-ferrous metal mining made a large contribution to the industrial development of Japan after 1868. Non-ferrous metal mining has a long history, but this paper aims to cover the period between 1868 and 1885 characterised by the coexistence of state and private mines. It is during this period that numerous novel techniques were introduced to the industry along with an influx of foreign engineers whose documented suggestions shed light on the possible causes of the problems faced by the mines. Particularly enlightening is the comment made by one such foreign engineer C. Netto that technological advances needed to be accompanied by the creation of unified mine management. This eventually took form when the traditional power of subcontractors under the old system fell and a new system emerged. The difference in the way state and private mines regarded foreign engineers is also notable in that it may explain the difference in the performance between them during this period. As a whole, foreign engineers played a vital role in

* The original version of this essay was presented to the Mining History Seminar at Dartington Hall (Devon, England) on 5/6 May 1984. The author's special thanks should be given to the participants in the seminar who gave him valuable comments and suggestions. But, of course, the author is solely responsible for errors and mistakes found in this essay. Since the seminar excellent works and valuable meterials have been published. H. Takeda (Tokyo Universiry) published a comprehensive book on the history of copper mining and smelting in Japan. Also to commemorate the first and the third centenaries of Dowa Mining Company (the owner of Kosaka mine) and Sumitomo Metal Mining Company respectively, interesting accounts of company history were compiled. However, the field still seems to lack a quick reference written in English, and in this sense, the author hopes this essay will be of some use.

the modernisation of mining in many aspects, but the efforts of the miners and the managers who quickly learnt from them must not be forgotten. Indeed by the end of the period, the Japanese miners and managers were ready to carry on with the modernisation by themselves into the next stage.

Key Words

modernisation of Japan, non-ferrous metal mining, technology transfer, foreign engineer, state mine, private mine, subcontract system, mine management.

1. Preface

Non-ferrous metal mining, especially copper mining, played a vital role in the process of industrialisation of Japan since 1868. The export of copper enabled Japan to acquire foreign currency which was essential for the importation of western technology. Western technology originally applied to this industry later became the basis of techniques in various other industries. Certain big companies emerged from this industry while old merchant capitalists were given an industrial base by it. These companies did not confine their activities to mining. The Ashio copper mine gave rise to the Furukawa group, which in 1938 manufactured electric wires, electric appliances and machinery, telephones, rubber products, chemical products as well as performing the mining and refining of metals. There was even a life insurance company belonging to this group. (2 : pp. 468-469)** Also the fortune of Sumitomo which later developed into a much larger "Zaibatsu" (a form of monopoly capital in pre-war Japan) depended heavily on the Besshi mine in the early Meiji era (Meiji era ; 1868-1912). Non-ferrous metal mining along with coal mining was among the first capitalistic industries in Japan, employing a large number of workers who had strongly inherited their traditional way of life from the past. Therefore, it is worth investigating the process of modernisation of this industry which involved the interaction between the modern capitalist system and traditional factors. Additionally, it provides useful materials to discuss the characteristics of the modernisation of Japan as a whole.

A number of detailed works on various aspects of mining, notably mining

** The first number in the brackets indicates the references.

technology, mining management, labour problems, problems of pollution, and company histories in relation to the histories of the "Zaibatsu", have been written up to now. However, most of them are written in Japanese, although attempts to introduce Japan's non-ferrous metal mines to the western world have been made since the early years of the Meiji era. (eg. 6 & 19) In 1980, Fumio Yoshiki published a monograph entitled "How Japan's Metal Mining Industries Modernised", the English edition of which is now available. (23) Emphasising the transformation observed in employment systems, he fully examined the problems which were caused by the introduction of western technology into Japanese metal mining. With reference to his work and other secondary sources, this paper will venture to sketch some aspects of the modernisation of non-ferrous metal mining in Japan.

2. Definition of the period

Firstly, we must define the period of modernisation. Japan has a long history of non-ferrous metal mining. A remarkable progress took place in the 16th and 17th centuries when warlords and later feudal lords (daimyo) as well as the Tokugawa Shogunate (military government) encouraged mining, especially gold and silver mining, in pursuit of wealth. The export of silver to China through Portuguese, Dutch, and British merchants flourished until the early part of the 17th century, when the Shogunate decided to limit silver exports. After this, the export of copper became predominant. Mining and metallurgical techniques also made significant progress during these centuries. The liquation process for separating silver from copper which was well illustrated in Agricola's *De Re Metallica* was introduced in Japan in the early 16th century and became firmly rooted in the 17th century. (12 : pp. 15–16 & Agricola Book XI) In Sado gold and silver mine, a type of Archimedes screw began to be used for drainage. In spite of its ancient origin, this screw proved very efficient. (See Hoover's *De Re Metallica* p. 149 footnote) It is said that these methods came from Europe both directly and indirectly with prosperous trade between Japan and other countries. The dialling technique which was applied to driving main adits of Sado mine in the 17th century is still admired for its accuracy. (12 : pp. 17–20) In the late 1690's, copper export and production appear to have reached the peak of Edo period (Tokugawa Shogunate period) with figures of 5400 tons and 6000 tons respectively. (5 : pp. 32–37) Throughout the Edo period, the right to operate mines, as well as mineral rights, basically belonged to the Shogunate or to the local governments of feu-

dal lords. However, actual mine operation itself was conducted by various types of subcontractors with names such as "Yamashi", "Kanako" and "Kaishi". More specifically, the Kanakos were involved with the actual mining itself and Kaishis dealt with the smelting and refining of ores. Yamashis customarily had firm rights for each lode of the mine, and under him were several Kanakos who had the right to extract ores from their own stopes using their own subordinate workers. The subcontractors were sometines responsible for the development of the mine, including mine drainage, at their own expense. Mine owners, that is the Shogunate or the feudal lords bought ores or refined ores in their various stages from the subcontractors. (21 : pp. 222–225)

After the end of the 17th century the decline of non–ferrous metal mines took place for a number of reasons, which will be discussed later. For example, the once celebrated Ashio copper mine which had produced nearly 1500 tons of copper in 1684 gradually dwindled in its production, until it only produced a mere 30 tons in six months in 1876. (2 : p. 45) Though some attemps to reverse this trend were observed at the very end of the Edo period, (14 : p. 69 & 23 : pp. 6–7) substantial reconstruction only truly began with the Meiji Restoration in 1868 when the newly–formed government was eager for gold and silver for coinage and self sufficiency in copper and other metals to prevent the increase of imports. Firstly, the Meiji government set to work in establishing the legal framework to encourage mining activity while protecting the industry from the influx of foreign capital. *Kozan Kokoroe* (Regulation of Mines) in 1872 and *Nihon Koho* (Japan Mining Law) in 1873 were clearly built on the principle that though the mineral rights belonged solely to the government, the right to operate mines should be open to the public except to foreigners. Since there were still some limitations on mining rights i. e. mines could not be mortgaged, it is hard to say that this was a radical step forward. Nevertheless, the latter was the first comprehensive law for mining until it was succeeded by the more liberal *Kogyo Jorei* (Mining Act) in 1892.

While constructing the legal framework, government funds were poured into the effort to establish modern mines by designating some as state mines, although most of these were gold and silver mines. A list of major mines designated as state mines and their share in the total production are shown in Tables 1 and 2 respectively. In such mines, hired foreign engineers and instructors were engaged in making plans for developing mines and training

Table 1 : Major Non-Ferrous Metal Mines under the Government Operation

Name of Mine	Major Products	Year of Designation	Year of Sale	Puchaser
Ikuno	Silver	1868	1896	Mitsubishi
Aikawa (Sado)	Gold/Silver	1869	1896	Mitsubishi
Kosaka	Silver/Copper	1869	1884	Kuhara
Handa	Silver	1873	1874	Godai
Ani	Copper	1875	1885	Furukawa
Innai	Silver	1875	1885	Furukawa

Source : (9 : pp. 48–148).

Table 2 : The Share of State Mines in Total Production (%)

Metals	1879	1880	1881	1882	1883	1884	1885
Gold	72	65	59	61	49	48	47
Silver	53	57	48	53	56	20	19
Copper	7	5	6	6	10	2	0

Note : Figures for 1879–1881 are those for April to March.
Sources : (8 : *Zoku* pp. 144–147) and (12 : p. 63).

Table 3 : Copper Production in Ani (State-run), Ashio (Private), and Besshi (Private) Mines

(tons)

Mine	1877	1878	1879	1880	1881	1882	1883	1884	1885
Ani	417	376	317	206	237	240	527	348	——
Ashio	46	48	90	91	172	132	647	2286	4090
Besshi	803	1021	983	1086	739	1167	1017	1028	1495

Note : Figures for Ani Mine in each year are those for July to June except for 1884 which ends in March 1885 due to the sale of the mine.
Sources : Ani (9 : p. 128), Ashio (2 : p. 82) and Besshi (14 : p. 153).

miners. The cumulative number of these foreign mining engineers totalled 78 up until 1884, if including those employed in iron and coal mines. The British chief mine engineer J. C. H. Godfrey, the French mine engineer F. Coignet, and the German metallurgist C. Netto were especially famous among them. Detailed information on these engineers is given in Appendix 3. The government also established Kobusho (Ministry of Public Works) in 1870 to operate these mines along with other state factories. After struggling to make these mines profitable, the government sold several mines to private entrepreneurs and abolished the Ministry in 1885. While the state mines were struggling for profit, the private mines, notably Besshi and Ashio, were constructing a firm base for development. Table 3 shows the copper production in the three big copper mines : Ani (the state mine, which was eventually sold in April 1885), Ashio and Besshi.

The period after 1885 appears to have been a period of diffusion and improvement of western techniques introduced into Japan in the preceding years, and of accumulation of private capital. During this period, the previously dominant foreign engineers and instructors were replaced by newly-trained Japanese engineers. Professors of mining and metallurgical technology were recruited from Japanese who studied under the foreign engineers or who had studied abroad. Most of the fully-equiped state mines were taken over by the mid-1890s by Furukawa, Mitsubishi, Kuhara etc.

But again the rate of growth began to stagnate towards the end of the 19th century due to a lack of adequate refining methods. The traditional method of roasting to remove sulphur from ores was becoming a bottleneck of the whole process, as the subsequent stages of refinement were becoming increasingly productive after the introduction of reverberatory furnaces. A breakthrough came with the adoption of pyritic smelting in Kosaka mine in 1900, which turned this old silver mine into a profitable copper mine. (12 : pp. 120-124) As smelting furnaces increased in size along with the utilisation of pyritic smelting, mines inevitably required large capital investment. The Ore Trading System developed : this was practice of purchasing ores from small mines by the smelting and refining works attached to the larger mines. Exploiting this system, a few large mining companies came to control the entire copper production, as well as obtaining a technological base for their dominance. (18 : pp. 72-75) Table 4 shows this trend. Therefore, the first decade of the twentieth century saw the coming of age of monopoly capital in

Table 4 : The Concentration in Copper Mining and Smelting Industry (%)

Years	1913	1917	1922
Copper Production of 11 Mines owned by the Largest 5 Companies.	62. 4	68. 0	91. 3
Copper Production of 11 Mines owned by the Largest 5 Companies, by smelting their own ores.	53. 7	44. 1	54. 8

Note : 11 Mines (Smelting Works); Ashio, Besshi, Kosaka, Saganoseki, Hitachi, Naoshima, Osarizawa, Arakawa, Mizushima, Yoshioka and Ani. 5 Largest Companies ; Furukawa, Sumitomo, Mitsubishi, Kuhara and Fujita.

Source : (18 : p. 72)

mining, which will be the subject of another story.

From what was stated above, it is possible to regard the period from 1868 to 1900 as the period of modernisation in non-ferrous metal mining, with a subdivision around 1885. The period from 1868 to 1885, where the coexistence of state mines and private mines was observed, can be regarded as the first phase of modernisation. This paper will deal with this period. To illustrate the overview of Japan's non-ferrous metal mines, especially copper, a map and a graph are given in Appendix 1.

3. Problems at the starting point

Many contemporary observers argued the causes of the stagnation of mining since the end of the 17th century, and they seem to be particularly reflected in the comments of two foreign engineers. F. Coignet who was employed by the government and the author of *Note sur la Richesse Minérale du Japon* ascribed the decline to the lack of proper techniques for mining. Explosives for excavating mines were virtually unknown. Therefore, the miners avoided hard rock formation and only exploited "soft and easy" ground with rich ore deposits. Pursuing ore lodes without explosives resulted in narrow and winding tunnels which were sometimes only 60cm wide and 60-90cm high. It led mine workings deeper and deeper, abandoning the comparatively poor but still usable ore deposits in shallow, hard-rock area of the mine. Deep mining

required proper equipment for drainage, ventilation, and haulage and problems arose when often the adits for drainage were blocked by the hard rock formation which was difficult to cut through with primitive tools. Also, narrow and winding tunnels made effective ventilation and haulage impossible. Eventually the stopes in deeper parts of the mine were also abandoned. Coignet also documented that an increase in mining costs due to a sharp rise of wages at the end of Tokugawa period probably acclerated the decline. (1 : pp. 39–40) Additionally, Coignet pointed out that the primitive methods of ore refining resulted in wastage. Much of relatively poor quality but still usable ores were left untreated. (1 : p. 43) However, after these arguments, he paradoxically insisted on the bright future of Japanese mining. He stated that because the stagnation of mining was largely due to the lack of technology, Japanese mining would become much more profitable if modern, cost–reducing technology was applied to it. For this, he implied the use of foreign capital. (1 : pp. 105–106) Thus, he knew that the problems not only lay in technology itself but also in economic factors.

Curt Netto, a German engineer, stressed the problems of the aged subcontract system broadly observed in mining as the main factor in the stagnation of the industry in his book entitled *Mines and Mining in Japan* (10 : pp. 137–138) As is the tendency in most subcontract systems, subcontractors like "Yamashi" and "Kanako" sought immediate and short term returns pursuing only rich mineral veins at the cost of necessary capital outlay for drainage, ventilation, and haulage. This tendency was encouraged by the policy of mine owners, who were not interested in the operation of the mines themselves but only in buying rich ores at the lowest price from subcontractors. It caused unsystematic development of mines. As Yoshiki argued, most of the technical deficits stated came from the old subcontract system. (23 : pp. 18–24) Therefore, the application of new technology to mining had to keep pace with the creation of unified mine management. In this study, though it is difficult to deal with these two aspects separately, we will first look at technological improvement and then mine management.

4. Process of modernisation 1— Technological aspects

Generally, the improvement of technique for underground working was slow in pace but substantial in kind. Rock–breaking method had to be improved for re–opening and widening old galleries and sinking new shafts for ventilation

and haulage. Practical use of gun powder began in Besshi mine in 1871 and diffused quickly after 1877 when the demand for gun powder for civil wars ended. (14 : pp. 168–169) At Besshi in 1882 and Ashio in 1883, dynamite blasting was also introduced for hard rock-breaking. (16 : p. 294 & 2 : p. 134) In comparison with the progress in using explosives, the use of rockdrills was in the experimental stage. In 1881, the first rockdrill was used for driving the adit for drainage at Yoshioka mine, but in the same year, the experiment to copy the Darlington-type machine failed in the government's Akabane factory. The first practical use of the Schram-type rockdrill started at Ani copper mine in 1882, and later were adopted at Ashio mine. (2 : pp. 131–132) From the very early years of the Meiji era, the overhand stoping method quickly replaced the traditional pickaxe method in most major mines. (14 : p. 183 & 4 : pp. 142–145) Though hand whims were commonly used for raising ores, installation of tramways in levels was widely observed towards the end of the period. (14 : pp. 200–204) Mechanically equipped drainage seems to have been limited but Cornish type plunger pump driven by steam engine was used in Sado mine in 1880. (14 : pp. 229–230)

Using new techniques of rock-breaking, large and systematic development of mines began. In response to the advice of L. Larroque, a French engineer employed by Sumitomo to devise plans for revitalising Besshi mine, the work for sinking new diagonal shaft started in 1876. (16 : pp. 328–329) At Ashio mine, large scale exploitation began after Furukawa took over the mine in 1877. (2 : pp. 62–63)

The modernisation of the process of surface work and refining ores showed remarkable progress. Many water-driven stamps were installed to dress ores, and several types of jiggers were also introduced to separate ores by size. For example, a Rittinger table was introduced in Ikuno mine. (10 : p. 54) As it will be seen later, part of Larroque's advice was the installation of new western-style pulverising machine to the dressing floor. (16 : p. 309) Furthermore, substantial modernisation appears to have begun with the improvement of smelting and refining techniques; this is suggested in Netto's work. Various types of amalgam method, i. e. Californian, Hungarian, and Freibergs, were introduced in gold and silver mines. (10 : pp. 54–55) For copper refining, wet-type refining showed good results at Besshi mine. Though Coignet had already suggested a similar method to reduce waste in 1873, this mine succeeded by the adoption of a different, "British type" method in 1878.

(16 : pp. 347–349) Before that year, wet–type refining had already become known because German engineers had introduced Zievogel and Hunt Douglas method to the state–run Kosaka silver mine. (10 : p. 55) In terms of mining economy, the improvement of the refining process to reduce waste had great significance. Since it took some years before the launch of new systematic exploitation, mine owners needed to achieve "quick benefit" from modernisation in order to finance large–scale development work. Various types of process of refining and smelting can be observed in major mines. They are illustrated in Appendix 2. Though the extent of details of description are different from each other, it is possible to recognize the mixture of modern and traditional methods. Perhaps the chart for Ani mine shows the most traditional method.

5. Process of modernisation 2— The creation of unified management

Modern mining techniques were also exploited in order to deprive subcontractors of their customary power. As already mentioned, in the traditional system, mine owners only bought dressed or partly refined ores from subcontractors. Miners used to bring ores back to their own houses to dress them which generated the possibility of concealing high quality ores to be sold for their own profit as well as leading to an increase in waste. In 1878, state–run Innai silver mine constructed a new dressing floor and smelting and refining works where all miners were expected to bring ores for further treatment. By raising the price at which the government bought dressed ores from subcontractors as precaution against possible opposition, the government gradually abolished the "Yamashi" and "Kanako" subcontract system by 1882. (9 : pp. 130–131) A similar idea, that centralised refining work can reduce the power of subcontractors, can be found in Larroque's suggestion for Besshi mine. He advised that Besshi should build a new refining work in Niihama, a site situated to the north of Besshi, to treat all its ores. To achieve this, transport between the mine to Niihama also had to be improved. This factor delayed full operation for several years before the work started in 1884. (16 : p. 340)

The direct operation of mines on a large scale by the mine owners themselves was also effective in reducing or eliminating the power of subcontractors. A typical example is observed in the case of Ashio copper mine. When Furukawa took over the mine in 1877, there were 33 to 38 subcontracters who had firm rights to their own stopes. One of them employed 41 men under

him. Immediately after taking over, Furukawa tried to enforce a tentative rule to regulate these miners, but its effectiveness was doubtful. In the same year, the direction of development seems to have been determined ; this included the large-scale exploitation of Takanosu adit and Honguchi adit under direct supervision. Furukawa apparently planned to absorb the traditional rights of subcontracters into the hands of the mine owners who were conducting the large-scale operations. In 1880, Kinoshita, the new chief manager of the mine, replaced "inferior miners" by "efficient miners" who were brought from another mine and also implemented a bonus system to accelerate the operation. Though the results were not remarkable, a tramway was installed in the mine and the miners were equipped with hand lamps. Within the private funds, this was the best they could afford. In 1881, they struck a rich ore deposit on the Takanosu lode. Immediately after that, they bought the traditional right to this lode from one of the subcontracters for 2,000 yen, a considerable sum at the time. They established directly-operated stopes on the lode. Afterwards, they concentrated on the exploitation of Honguchi adit, where in 1883 they again struck rich deposits and also established directly-operated stopes. Since these were the most productive lodes, everything in the mine was eventually organised around them. It meant that most of traditional rights of subcontracters were virtually absorbed into Furukawa's hands. (2 : pp. 55-66, 83-85)

Other similar examples were found in many mines although those did not always signify success. In the state-run Ani copper mine, the government tried to use a group of newly-trained miners for the creation of direct operation. (9 : pp. 122, 124) The privately-run Besshi mine was developed basically but not entirely according to the plan devised by Larroque. Large-scale development was conducted under the direct supervision of the chief manager. These included the new diagonal shaft started in 1876 and completed in 1895, main tunnel No. 1 to facilitate transport from 1882 to 1886, and Koashidani main adit for drainage completed in 1886. (16 : pp. 325-338)

Along with the increase of the operation directly supervised by mine owners using modern techniques and expensive machinery, the old subcontract system gradually lost its significance and was transformed into a new type of subcontract system often called the "Hanba" system. In this system, subcontractors no longer had the right to participate in the decision-making but only supplied labour on demand from the mine owners. Although the

general working rules of the mine were directly imposed on miners, the subcontractors partly conducted labour management for mine owners. (21 : pp. 257–265)

The question arises as to whether there were any serious opposition from the subcontractors. Unavoidably, there were problems. Various forms of subotage including arson were observed in several mines especially state mines where western technology was rapidly introduced. Sometimes, as in the case at Innai silver mine, the symbolic visit of Emperor Meiji was efficiently used to calm the disorder. (23 : pp. 45) Some mines like Ani and Innai asked the government to station policemen. Small resistence continued, fuelled by the fear of unemployment and loss of the benefit derived from the traditional system. But in general, the opposition was overcome in a comparatively short period. Examining the reasons for this would be an interesting subject for another paper.

6. The role of state mines and foreign engineers

As already stated, this period is characterised by the existence of state–run mines and the employment of western engineers. To conclude this paper, it is necessary to evaluate the role of these mines and engineers in the light of the modernisation of mining.

From many measures of production and profit and so on, the general impression is that state mines were not successful as the large private mines like Ashio and Besshi. Perhaps as Netto properly explained, the poor performance of state mines can be ascribed to "the destiny of model mines" ; the aim of these mines was not profitability but the conduction of various experiments in advancing mining technology. (10 : p. 50) Perhaps private mines like Ashio and Besshi were just exceptionally lucky. However, to some extent, the difference of management system, particularly in the position of foreign engineers between them appears to have been responsible. Yoshiki pointed out that the difference in the nationalities of foreign engineers caused disorder when introducing new techniques and machinery. For instance, while Kosaka, Ani, and Innai mines situated in the north–eastern part of Japan were strongly influenced by German engineers, Ikuno silver mine and Sado gold mine were instructed by the French and the British respectively. This is well illustrated by the different types of amalgam method which each mine adopted

for refining gold and silver. (23 : p. 27)

Apart from this inevitable consequence, the position of foreign engineers in the process of decision-making in state mines appear to have been different from that in private mines. The difference between Ani and Besshi mines can be clearly seen.

Ani copper mine which had been designated for government operation in 1875 and eventually sold to Furukawa in 1885 was a relatively good copper mine. However, it recorded huge losses towards the end of the period concerned. After its designation as a state mine, foreign engineers Godfrey and Coignet inspected the mine in 1878 and proposed large-scale operation for the development of the mine also involving Innai mine which was in the vicinity. Coignet estimated that a total capital of 2, 002, 600 yen would be required for the plan. (9 : p. 123) In the following year, a German engineer called Mezger, modified Coignet's plan and also recommended a 1, 450, 000 yen plan including the construction of a large smelting and refining work which would cost 244, 000 yen. (9 : p.124) Both plans were basically approved by the government and large state funds were poured into the mine. Initially, the plans devised by Coignet and Mezger seem to have had priority since the government was eager to concentrate merely on the technological facet of development. As supply of capital was abundant, economic factors did not come into consideration until state funds became restricted to 1, 290, 000 yen in 1881. Soon, there was realisation that the plans were a burden. For example, in 1884 they admitted that the process of smelting and refining originally designed by Mezger in 1879 was unsatisfactory in its fuel consumption, and to improve it would require 100, 000 yen and another three years, causing the government to consider selling the mine. (9 : p. 127)

In contrast, the case of the privately-operated Besshi mine was rather different. At the start of the Meiji era, even this rich mine could not escape the general stagnation of non-ferrous metal mining in Japan. This mine was suffering problems generally caused by deep mining such as flooding, and haulage and ventilation difficulties. (16 : p. 292) To revive this mine, the chief general manager Saihei Hirose invited Coignet to inspect the mine in 1873. Hirose had once trained under Coignet in Ikuno mine. After inspecting the mine, Coignet suggested that regardless of whether the mine was rich or poor, an introduction of wet-type refining of copper ore would be profitable

for reducing waste. (16 : pp. 300–301) The mine manager started preliminary study for implementing the method, and it was later put into practice with the aid of British engineer Godfrey. (16 : p. 348) While preparing for wet–type refining, Sumitomo, the owner of the mine, employed the French engineer L. Larroque to inspect the mine and devise plans for development in 1874. During his one–year stay, Larroque expended considerable effort and submitted instructions to the mine manager when he departed. His instructions consisited of four topics as follows. (16 : p. 309)

The improvement of the underground facilities including the work for opening new shafts and levels

The improvement of transport facilities, both underground and surface, including the construction of new roads and railways

The construction of new smelting and refining work in Niihama including the manufacturing of bricks for construction work

Installation of new western machinery, underground and surface.

Though his instruction was well considered, Sumitomo and the general manager, Hirose, did not put the plan into practice as it was. They held a firm belief that the duty of foreign engineers should be confined to giving advice based on their expertise. Therefore, while noting Larroque's plan, Hirose came up with a different "practical" plan taking into consideration their financial position and instructions of a British engineer, Robert Freshville, who happened to visit the mine for one week. (16 : p. 321) Sumitomo and Hirose started developement work without the aid and supervision of foreign engineers. According to Larroque's original plan, foreign engineers were an essential part and their wages would have estimated 138, 000 yen out of the total budget of 673,000 yen. Perhaps unlike in state mines, limited supply of capital in private mines forced them to consider most of all the economic rationality. In consequence, the strategy brought about high economic performance.

As it has been mentioned, in the privately–run Ashio mine, the creation of unified management was accomplished by combining the subcontract system with a bonus system while minimising capital outlay for machinery but expanding direct operation. Furukawa made rational decisions for development which also took economic factors into account. This was so even though Furukawa stood on an advantageous position, being supported financially by Shibusawa's Daiichi Kokuritsu Ginko (First National Bank) and politically by

Munemitsu Mutsu, an influential politician. (2 : pp. 62–63) This was in contrast to some state mines which were mainly interested in technological innovation.

What role did foreign engineers play in mining in Japan? It can be said that they made valuable contributions to the technical advancement. They not only introduced western techniques, but also trained Japanese mining engineers and miners, enabling them to carry forward the next phase of modernisation of this industry. Furthermore, they helped to establish institutions of mining and metallurgical education. They were headed by Imperial College of Technology and Faculty of Science, Tokyo University. The latter eventually absorbed the former, and their graduates became the leaders in the development of mining and metallurgical technology. (23 : pp. 49–51) It is no exaggeration to say that modern mining and metallurgical techniques in Japan were founded by them. However, the effort and skill of the Japanese managers who made enlightened decisions, and the Japanese miners who rapidly learnt new techniques from the foreign engineers must not be forgotten.

Also it should be noted that decision making on purely economic basis often made labour conditions and pollution worse. These aspects have been purposely left out in this paper in order to concentrate on the modernisation. Perhaps further review of the meaning of "the modernisation" itself will be required from a wider perspective.

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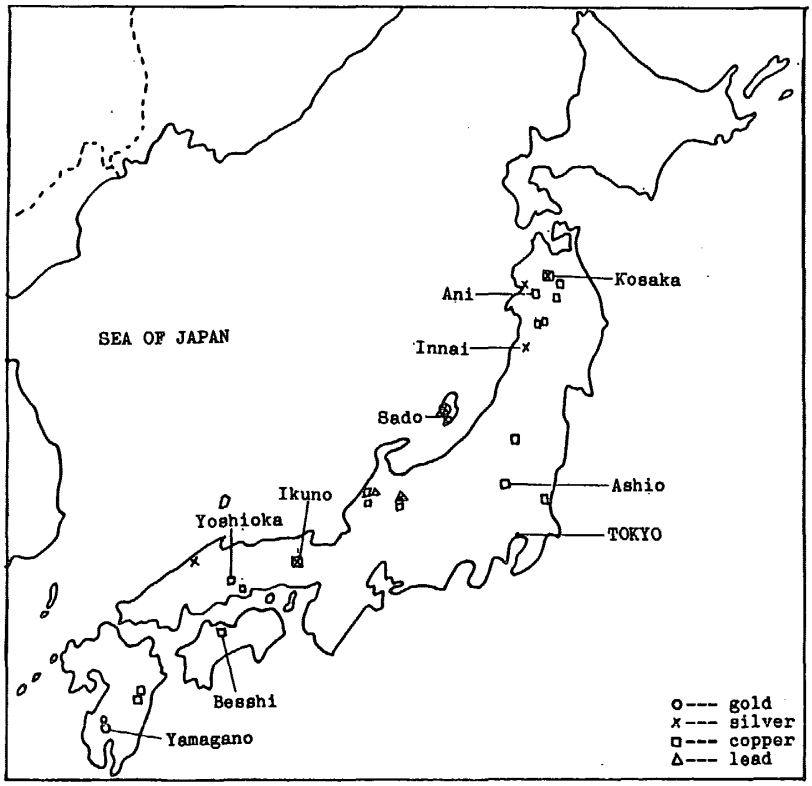
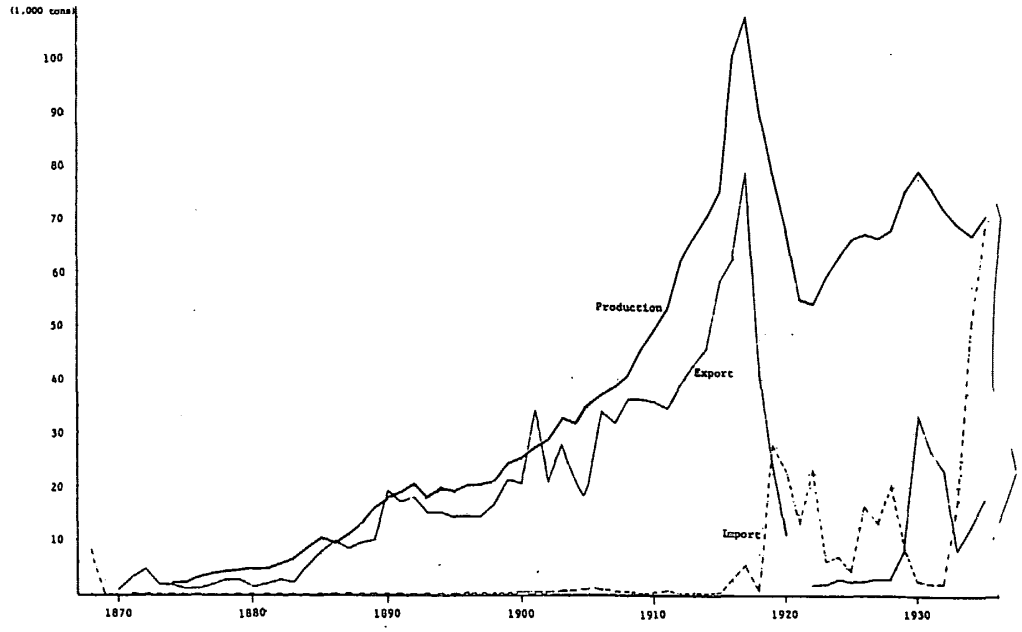
Appendix 1-a

Location of Major Non-Ferrous Metal Mines in Japan in the early 20th Century



Appendix 1-b

Production, Export and Import of Copper, 1868–1935

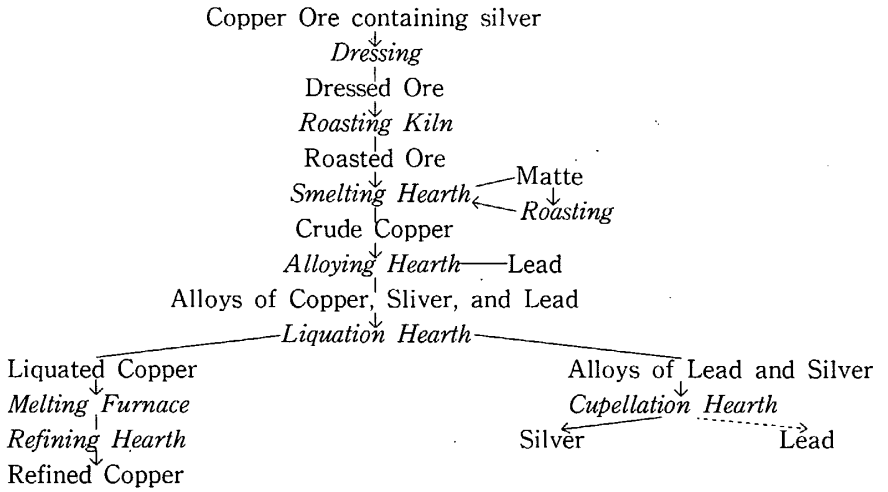


Source : (8 : *Sei* pp. 311, 746 & 775) and (8 : *Zoku* pp. 128, 204 & 206).

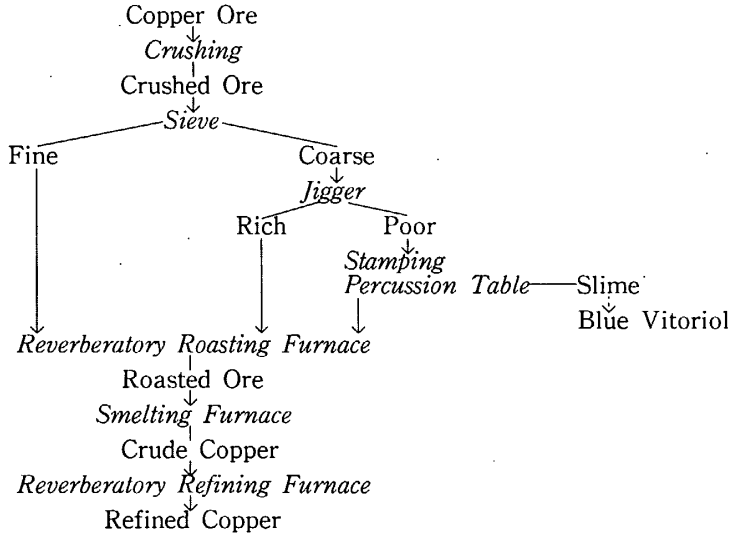
Appendix 2

Smelting and Refining Processes in Copper Production around the Mid-1880s

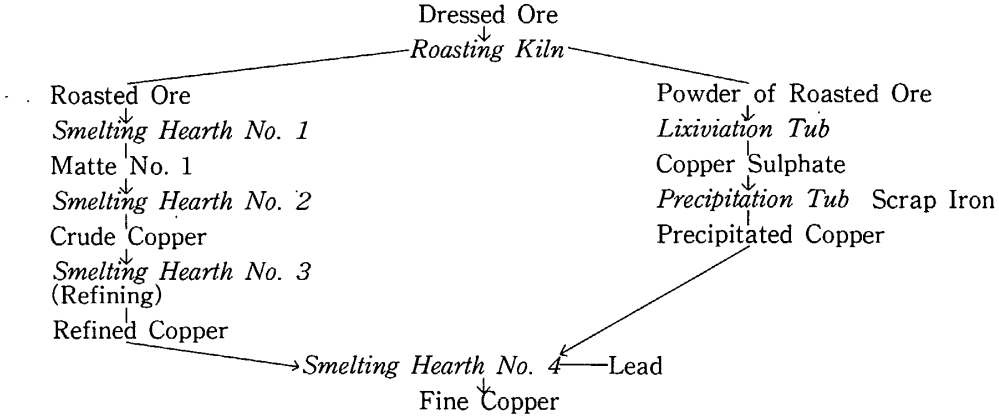
Ani Copper Mine.



Asio Copper Mine.



Besshi Copper Mine.



Sources : (12 : pp. 92–103) and (14 : pp. 446–448)

Appendix 3

Foreign Employees at the State-Run Non-Ferrous Metal Mines including the Head Office in Tokyo

Name	Nationality	Job description	Place of Work	Monthly Salary	Period of Employment
François Coignet	French	Mining Engineer	Ikuno	800 yen	1868–1877
E. H. M. Gower	British	Ore Preparation	Sado	600	1869–1873
Piquet	French	Miner	Ikuno	91	1870–1871
Ruby	French	Miner	Ikuno	91	1870–1871
Pauli	French	Miner	Ikuno	91	1870–1871
Denis Sevoz	French	Geologist	Ikuno	570	1870–1871
James Scott	British	Instrumentation etc.	Sado	280	1870–1881
J. C. H. Godfrey	British	Chief Mining Engineer	Head Office	1000	1871–1877
Emile Mouchet	French	Geologist	Ikuno	700	1871–1880
Alphonce Palisse	French	Brick Layer	Ikuno	120	1871–1873
Malroux	French	Miner	Ikuno	130	1871–1873
François Allan	French	Miner	Ikuno	130	1871–1873
Antoine Géraud	French	Miner	Ikuno	130	1871–1874
Pierre de Heunard	French	Miner	Ikuno	130	1871–1874
Lescasse	French	Geologist	Ikuno	300	1872–1872
Augustin Henneton	French	Medical Officer	Ikuno	350	1872–1875
Jacques Lagrand	French	Smelter Worker	Ikuno	150	1872–1874
Jean Lustemberger	French	Mechanic	Ikuno	200	1872–1878
Claude Verner	French	Mechanic	Ikuno	200	1872–1876
Frederick Hayes	British	Secretary	Head Office	260	1872–1876
Paul Lerme	French	Smelter Worker	Ikuno	120	1873–1880
James Dale	British	Miner	Sado	80	1873–1874
John Simmons	British	Miner	Sado	80	1873–1876
Thomas Treloar	British	Miner	Sado	120	1873–1877
Georg Martin	German	Instructor	Head Office	260	1873–1873
Lén Sisley	French	Geologist	Ikuno	300	1873–1878
André Bosch	French	Miner	Ikuno	103	1873–1876
William Bell Davis	British	Instructoe etc.	Head Office	365	1873–1876
Robert T. Carlyle	American	Mining Engineer etc.	Okuzo	415	1873–1875
Joseph Walters	British	Assistant Chief M. E.	Head Office	415	1873–1874
Alexis Janin	American	Mining Expert etc.	Sado	525	1873–1876
Adolf Reh	German	Excavation Expert	Sado	400	1873–1878
Curt Adolf Netto	German	Mining Expert	Kosaka	450	1873–1877
Robert Freshville	British	Instructor etc.	Head Office etc.	370	1873–1876
Joseph Lustemberger	French	Instrument Expert	Ikuno	200	1874–1879
Charles Hagmaier	German	Instrument Expert	Kosaka	250	1875–1877
Jean Lenoir	French	Miner	Ikuno	200	1875–1880
François Maillet	French	Medical Officer	Ikuno	300	1875–1875
William Thomas Brown	British	Instrument Expert	Okuzo	150	1875–1876
Repiquet Lamy	French	Forge Worker	Ikuno	150	1876–1879

Charles Boudoir	French	Instrument Expert	Ikuno	200	1878–1881
Adolf Mezger	German	Chief Instrumentation	Ani	500	1879–1882
F. W. Reichl	German	Mine Foreman	Ani	150	1879–1882
Oswald Pfeiffer	German	Mine Foreman	Innai	150	1879–1882
Christian Bansa	German	Chief Instrumentation	Innai	500	1879–1882
W. Heise	German	Mechanic	Ani and Innai	250	1880–1882
Fritz Schwinn	German	Ore Washing Foreman	Innai	125	1881–1882
B. Roesing	German	Smelting Engineer	Innai	300	1881–1883
von Weyer	German	Assisttant M. Engineer	Ani	250	1881–1883

Sources : (9 : pp. 91–93), (22) and (23).