THE BAWDWIN MINES

By J. D. HOFFMANN.

FEW of the ore-bodies opened in recent years have attracted more attention in the mining profession than those now being developed by the Burma Mines, Limited, at Bawdwin; and not without good reason. Mining here certainly began as early as the 15th century, and an enormous amount of metal has since been taken out, an amount that it is impossible to estimate with any degree of accuracy. In the brief period since the resumption of mining under European control, the total income from the sale of products has been approximately £1,000,000. This, with a like amount of new capital, has been spent in construction, working costs, and development. During 1916 it is expected that all operating and construction costs can be paid out of current profits from a small operating unit, part of which was originally designed for testing only. While much has been written about the Bawdwin mines, it will perhaps prove serviceable to have a general summary of their history and of the present status of the enterprise. At the request of the editor, I am, therefore, glad to furnish this.

The Bawdwin mines are in the Northern Shan States of Burma, within about 50 miles of the Chinese border. They are connected with the Burma Government railways by means of a 50-mile 24-in. gauge line, built by the mining company, from the mines to Manpwi on the Mandalay-Lashio line. Manpwi is 169 miles from Mandalay, and 554 miles by rail from deep water at Rangoon. The branch railway owned by the mining company traverses a heavily wooded mountainous country with deep-cut ravines and soft treacherous banks that have made both construction and maintenance expensive. I may anticipate by saying that it was built as cheaply as possible to afford transportation for a definite amount of rich slag left by the old Chinese miners, and which formed the basis of the first resumption of smelting. It was adequate for the purpose, but in order to make it serve the larger needs of the present, it has been necessary to repair large portions of the line. Recently it was shortened five miles and a new junction made with the Burma railways at Nam Yao. Doubtless if the present situation could have been anticipated and the possibility of using the road as part of a trunk line to China properly appreciated, a different sort of a railway would have been built. It is well to remember that it is a very different matter to prepare for transporting 115,000 tons of slag, the amount estimated by Mr. C. S. Herzig as contained in the dumps—a forecast which, it may be stated, proved excellent though slightly conservative—and to prepare for a great mining enterprise lasting through a period of years. It is worth bringing out these facts, since much of the discouraging delay of early years was due to defects in the transportation, and a glance through the photograph books of the old company might mislead one into thinking that the locomotives spent most of their time rolling down embankments.

HISTORY.—The early history of the mines is obscure. The best general statement was compiled with much labour by Dr. Malcolm Maclaren in 1913. As it has not been published, I shall make liberal extracts from the manuscript. According to Maclaren, from the 5th to the 13th centuries the vicinity of the mines was probably in the hands of the Shans. Early records mention in detail the finding of gold in the 7th and 8th centuries, but no mention is ever made of silver. This omission would strongly indicate that the Shans, who were never real miners, did not work the Bawdwin mines. Following the Mongol invasions information is lacking as to the country taken and retained by the Chinese, but it is probable that Bawdwin was not occupied by them until the invasion of 1343 A.D. The Chinese, according to one inscription, started work at Bawdwin during the Ming dynasty in 1412. No doubt the Shan power terminated about this date, and the Chinese invasions of 1582 A.D. deferred their getting another footing. It may be inferred that the mines were worked exclusively by the Chinese from the
15th century on. Recent Chinese records show that the Bawdwin mines were worked from 1796 to 1851. During this period the mines were within what was nominally Shan territory and the Chinese paid a very small royalty to the King of Burma. The mines appear to have been governed by a president (Ta-Yeh) and a vice president (Erh-Yeh) elected by the miners.

The first European to mention the mines was Michael Symes in 1795. He stated that they were at Badowem, six days journey from Bamoo (Bhamo). In 1827 Crawford, who came into contact with Chinese traders from Bawdwin, estimated the production of silver at £120,000 per annum and the royalty paid to the King of Ava was £600. He was told that 1000 men were working. In 1855, it is said only 40 ticals of silver (£5) were paid to the King of Ava, although Dr. Oldham was told that 10,000 Chinese were working at Bawdwin. The apparent discrepancies between the number of men at work and the royalty paid is not thought to mean a decreased output at the mines, but to indicate the waning of the power of the Burmese kings to collect their royalties. Dr. Oldham further states that about this time the output of the mines was 2130 oz. silver per day derived from ore assaying 163 oz. of silver per ton. No doubt these figures are exaggerations, but may be accepted as showing that operations at the mine were at least active in 1855. Mr. Taw Lein Ko, the government archaeologist of Burma, estimates that the Chinese community contained fully 20,000 people. To the west, northwest, and north, old fortifications may be seen covering a distance of 12 to 14 miles. At the site of the village the main stone-paved road and the ruins of numerous dwellings and temples still remain in the valleys and on the hills. The stream was kept under control by well built retaining walls. Three stone bridges are still intact. Many graves are scattered over the hillsides.

In 1855, the Panthay (Chinese Mahommedan) rebellion started, and devastated the country until 1873. The Panthays, with their success and skill in mining, aroused the jealousy of the Taouists, and minor conflicts gradually grew into a huge struggle throughout the whole of Yunnan. In 1873 the rebellion came to an end by the capture of Tali-fu and the treacherous massacre of 30,000 Mahom-
Pang Sang Village.
Bungalow, Namtu, before the Smelter was built.

medans. It is estimated that from three to four millions of people, including women and children, had perished, and Yunnan was left devastated and in no condition to continue mining. During the confusion the Kachins preyed upon the community at Bawdwin, cutting off the incoming supplies of charcoal and fuel wherever possible. This seems to have determined the final retreat of the Chinese. When the abandonment of the mines did take place in 1868, it is said to have been so precipitate that 78 mule-loads of silver were hidden and abandoned and have not yet been found. No doubt the departure of the Chinese put an end to successful and continuous mining operations until the advent of the first English company formed in 1902. In the meantime, the Burmese Kings, Mindoon Min and Thibaw, sent "armies" to work the mines, but owing to epidemics and a lack of mining and metallurgical skill, the work was soon abandoned.

After this early period of which Maclaren has written, nothing of importance occurred until January 1901 when Aviet T. Sarkies, a merchant of Rangoon, was induced to visit Bawdwin by a Burmese who roused his interest by a wonderful tale of the riches of the mines in silver, lead, and zinc, and the piles of slag running high in lead. The first move was to have the property examined by W. A. Freymuth, who represented Messrs. Sulman & Picard. The report set forth that a smelter and a narrow-gauge railway were warranted. Other reports were made by Messrs. F. D. Chase and C. S. Herzig, and subsequently the Burma Mines, Railway & Smelting Co., Ltd., was formed in March 1906. In May 1908, the name of the company was changed to Burma Mines, Limited.

In December 1908, the railway was completed from Tiger Camp to Manpwi. The next year the line was completed to the mine. A smelter was erected at Mandalay and the first furnace was blown in during February 1909. After two years of smelting, the smelter was removed to Namtu, a point only 12 miles from the mine. Since that date smelting operations have been carried on continuously, the production of lead being about 1000 tons, and of silver in lead bullion 22,000 oz., per month. The present rate of production is somewhat higher, and is being increased. The total production since the starting
of the smelter in 1909 to the end of October 1915, has been 66,000 tons of lead and 1,432,000 oz. of silver, which was derived from 158,000 tons of old slag and 35,000 tons of ore, and on which over £1,000,000 has been realized. During the whole period of slag smelting operations, the engineers were curious as to the source of the ores from which the slags were derived, and the possibility of developing a valuable mine in the neighbourhood of the old Chinese workings at Bawdwin was of course in mind as more and more capital was put into the enterprise. Only desultory prospecting was carried on in the old caved workings until 1911, when active mining operations began. From the start, although this work was attended with unusual difficulties, the results have been uniformly successful. It was in 1913 that the great Chinaman orebody, which constitutes the present chief feature of interest, was penetrated.

GEOLeGY.—The geology of the Northern Shan States has been described recently in some detail by Sir Thomas Holland and G. H. Tipper in a bulletin on 'Indian Geological Terminology,' issued by the Indian Geological Survey. A brief abstract, with a small geological map, appeared in The Mining Magazine for August 1914. The oldest rocks in the region are certain granites, gneisses, and schists occurring in the northwest. On them rest Cambrian beds consisting of the mica schists of Mong Long, above which is the Chaungmagyi series of unfossiliferous red, purple, and grey quartzites, slaty shales, and felspathic grits. These rocks are in turn covered in the neighbourhood of the mine by the Bawdwin volcanic series of grits, tuffs, and rhyolites. The older sediments, and presumably the volcanic series, were deformed and eroded before being covered by Ordovician sediments. Erosion has since exposed the whole series. The rocks near the mine have been discussed further by T. D. La Touche and J. C. Brown, who point out the dominant structural feature of the region, a great overthrust fault which has been traced about 30 miles. Bawdwin is near its northern limit and where a minor line of disturbance branches off from it. The orebodies are thought to have structural and genetic relations to this zone of faulting.

Our principal source of information regarding the geology of the mine itself and immediate surroundings is an unpublished report by Dr. Malcolm Maclaren and the semi-monthly summaries of observations by Mr. M. H. Loveman, the geologist for the company. No complete detailed topographic and geologic map has yet been made. Maclaren recognized an upper and a lower sedimentary series and one of igneous rocks. The upper or 'Banyan' series of beds, consists of quartzites, sandstones, and shales. These rest unconformably upon the lower rocks, have been largely cut away by erosion, and have no relation to the orebodies. The lower sedimentary series, the Bawdwin beds, consist of felspathic grit, and were considered by him to be the ore-bearing beds. Below are the tuffs and lava flows of the rhyolitic series. The rhyolites and associated tuffs were found exposed in a belt of country about one-half mile wide and extending in a northwest-southeast direction. The southwest boundary of the rhyolite was thought to have been determined by a fault plane for the greater part of its course. The rocks near the mine were mainly tuffs and breccias, but to the northwest true flow structure showed. The Bawdwin beds were described as being homogeneous grey felspathic grits becoming coarser grained in places until they present a brecciated appearance. It was suggested that in part they might be ash beds. The ores known at the time of Maclaren's study were in these beds. It was held that the rhyolites were the oldest rocks locally present, and that they were covered unconformably by the two closely related sedimentary series of which the basal one was pyroclastic. The faulting took place prior to ore deposition, the planes affording the channels through which the ore-depositing solutions found their way into the easily replaced grits. Two major nearly parallel faults about 500 ft. apart were recognized, with several cross faults. The orebodies were held to have been formed through replacement in that part of the formation best suited to this action. Prospecting to the north was discouraged, since in that direction the more massive rhyolite replaced the grits, but it was Maclaren apparently who pointed out that the structure favoured the finding of ore under the overlying cap of sediments to the south, where in fact, the big Chinaman orebody, which was indicated by a large open cut on the surface, has since been found. He also pointed out the limits of the zone within which prospecting has since proved so profitable, and he indicated that the ore would probably be found to continue in depth so long as the shear zone continued in the felspathic grit.

*In the following account of the geological conditions I am indebted to H. Foster Bain for segregating the important facts from the available information.
† Engineering & Mining Journal, Sept. 18, 1909.
Mr. M. H. Loveman, who has served as geologist to the company since December 1914, has confirmed fully Maclaren's main conclusions, though he has modified them in certain significant particulars. In general his work has emphasized the close relations of the felspathic grit and the rhyolite. In the lower levels the fresher rock shows that the ore is in true rhyolite, a conclusion which Maclaren accepts, and in the upper levels the felspathic grit is held to be, in part at least, merely altered rhyolite. Mapping the rhyolite in detail has shown the area of outcrop to be irregular and the boundaries to be determined not by a faulting contact, but by the change from altered to unaltered rhyolite. There is then still to be solved here the same problem of relative importance of true igneous rocks and of pyroclastics in a great volcanic series that has led to controversy at Tonopah in Nevada, at Waihi, and in other districts. So far the bottom of the rhyolite flow has not been found, and the question suggests itself whether intrusive rocks as well as inflowing waters, by any chance, enter into the problem. The matter is not of immediate economic importance, since the amount of ore already found is more than ample for many years of working. By the time it does become important the geologists will doubtless have worked out the problem. For the present it is sufficient to say that the orebody occurs in an ancient volcanic series, in part under a sedimentary capping, and that it was formed through replacement, presumably by ascending deep seated waters near the locus of
important fault planes, where a coarse tuff afforded a particularly favourable habitat. There is, according to both Maclaren and Loveman, no evidence of secondary enrichment in the orebodies now opened up.

**Development.**—When it was decided to attempt re-opening the mines, the first work consisted of cleaning out some of the old Chinese adits and workings. It was soon recognized that several orebodies existed which came to be known as the Shan, Burman, and Chinaman lodes, but their relative sizes and richness were not then known. It was decided to prove the Shan and Burman lodes by means of a vertical shaft and to open up the Chinaman orebody through the already existing 'Dead Chinaman' tunnel and also by means of an incline shaft.

By the end of 1913 the vertical shaft had reached a depth of 339 ft. The Burman lode had been opened up at the 102, 171, and 300-ft. levels, and the Shan lode at the 50, 102, and 300-ft. levels. Other smaller lodes, the Dormouse, Palanung, Kachin, etc., were found. All of this work, as well as that during the first few months of 1914, showed that this part of the ore channel was greatly disturbed, the orebodies being erratic and faulted. The Burman lode varies in width from 1'6 to 4'7 ft., and contains lead-zinc ores of varying value. The Shan lode is narrow on the 102-ft. level, and also contains lead-zinc ore; on the 171-ft. level it pinches to almost nothing; on the 300-ft. level it opens into a large body of copper ore; and on the 430-ft. level lead-zinc ore again predominates. A considerable quantity of good ore will be won from this part of the mine, but the tonnages and value cannot be intelligently estimated as yet, and have therefore not been included in the recent ore reserve estimates, which refer entirely to the Chinaman orebody.

While this work was proceeding from the vertical shaft, the opening of the Chinaman lode was also under way, although, prior to 1913, very little was accomplished. The Chinaman tunnel had been driven to the point of entering the southern extremity of the orebody. A cross-cut from the incline shaft penetrated only a low-grade unimportant orebody. Later developments have proved that the main lode had been cut off by a fault before reach-
ing a point as far south as the incline shaft workings.

During 1913, the Chinaman tunnel (the No. 2 or 171-ft. level) was driven about 1000 ft. within the orebody, and cross-cuts were put out at eight different points. The lode was shown to average 55 ft. in width with a maximum width of 113 ft. and the value of the ore was found to be excellent. The No. 1 (102 ft.) level penetrated the north end of the orebody for a distance of 150 ft. This work was sufficient to indicate the great possibilities and importance of the Chinaman orebody, and a more systematic and extensive schedule of development was laid out. More capital was required for such an undertaking, and in October 1913 the Burma Corporation Ltd. was formed, and bought a controlling interest in Burma Mines Ltd. That corporation also became the general managers of the property, succeeding Bewick, Moreing & Co., who remained as consulting engineers. Later the Corporation acquired additional holdings until now it owns a majority of the debentures and over 99% of the shares of Burma Mines, Limited.

To explore the lode below the Chinaman Tunnel, an internal shaft was started from this level at co-ordinate 1510 ft. south, and also a winze at 1135 ft. south. A favourable tunnel site was found in the Sterne River valley convenient to the railway, and nearer to the smelter, which would permit of an adit being run to cut the orebody at a depth of about 660 ft. below the collar of the vertical shaft, and such an adit, the Tiger Tunnel, was started. This tunnel, which will reach the ore channel at about 6000 ft. in, will then be turned to follow the strike of the lode. It will serve to drain the mine and to be the main haulageway for the ore. Having in view the heavy rains in this, a tropical country, the Tiger Tunnel is important not only because it affords drainage and transportation in an ordinary sense, but also because it obviates the necessity of keeping up a long expensive surface line. The internal shaft has attained a depth 500 ft., 19 ft. below the Tiger Tunnel level, and has been stopped pending a connection being made with the Tiger Tunnel. Levels Nos. 3 (300 ft.), 4 (430 ft.), 5 (540 ft.), 6 (653 ft.) were started from this shaft. Winze 1135 ft. south was stopped at a depth of 301 ft. as considerable water was encountered. Levels Nos. 3 and 4 were also started from the winze. Drifts have been put out to the north and south from
both winze and shaft and also a number of
cross-cuts to the limits of the orebody. Due
to sinking and pumping operations requiring
the greater part of the cross-section of the
shaft and of the hoisting capacity, the develop-
ment of these levels is proceeding at a moder-
ate rate, and to date none of them is complete.
Levels 5 and 6 are hardly more than started.
The most striking features of the develop-
ment below the No. 2 (171 ft.) level are the
almost entire absence of old Chinese workings,
and the finding of large quantities of exceed-
ingly rich silver-lead ore. It is to be assumed
that in the upper workings the Chinese mined
out most of the ore of this character leaving
only patches of it here and there. The ore
reserves naturally increase very rapidly in an
orebody of such great size as lateral develop-
ment proceeds at the different levels. The
Technical Committee of the Burma Corpora-
tion Ltd. estimated the reserves of proved
and probable ore to November 1914 at
1,310,000 tons having an average value 19.8 oz.
silver, 23.2% lead, and 21.6% zinc. In August
1915 the estimate of reserves was 2,000,000
tons averaging 25 oz. silver, 27% lead, and
22.5% zinc. This augurs well for the final
tonnage which should be exposed above the
Tiger Tunnel or No. 6 level, when the full
area of ore has been opened up on each of the
Nos. 3, 4, 5 and 6 levels.

MINING AND TREATMENT.—The early
history of the financial difficulties, the forma-
tion of the different companies, railroad build-
ing, the smelting of old Chinese slags for lead
and silver, the development of the lodes, etc.,
has been briefly stated, and there still remain
the important considerations relating to the
metallurgical treatment and disposal of the
various classes of ore, and the methods to be
used in mining them.
The methods of mining the ore are depend-
ent upon factors which are as yet not defin-
ately solved. The assay plans of the mine
show that large bodies of different classes of
ore occur in compact masses, and that select-
ive mining can undoubtedly be done. Selective
mining may therefore control details of the
method of extracting the ore. The methods
of stoping which will be found practical and
commercially advisable can only be finally
determined after a thorough study of all the
questions involved, the metallurgical results
which can ultimately be obtained from con-
centration, smelting, etc., and the selling
contracts for ore and concentrates. These
questions are in capable hands, and no con-
siderable difficulties are expected.

The Bawdwin ores are complex in nature,
and members of the technical staff have been
alive to the necessity of making many tests
to ensure a practical and commercial separa-
tion of lead and zinc concentrates, and for
their treatment or disposal. Before the war a
good profit was made from shipments of 2000
to 3000 tons of ore per month to Europe, show-
ing that there is a good market for certain
ores without preliminary treatment.

A large shipment of ore was made to the
Zinc Corporation at Broken Hill and treated
in its testing works with encouraging results.
A testing plant was erected at Namtu, and
operated on a small scale for about one year.
The results warranted the enlargement of this
plant to a capacity of 100 tons per day, the
mill to be utilized not only for experimenting,
but to crush ore and to make concentrate for
the lead smelter. The mill has been com-
pleted, and is now sending about 500 tons per
month of crushed high-grade silver-lead ore
and concentrate to the roasters, whence it goes
to the smelter where it is smelted with the slags.
The chairman of the technical committee
stated in his speech before the shareholders
at the last annual meeting that this procedure
would be continued during 1916, substituting
more ore and concentrate for slag as the
latter becomes exhausted. It is expected in
this way to realize a profit over all expendi-
ture for the year.

The metallurgical position may be briefly
summed up as follows: Experiments in con-
centration have shown that lead and zinc con-
centrates can be made which indicate a profit
of about £2. 10s. per ton of average grade
ore, but more testing is required to perfect
this separation in order to minimize the metal
losses and increase the profits. The smelter
can continue to make good profits from silver-
lead ores as at present. After the war, no
doubt, the zinc concentrate and certain picked
ores can be shipped and sold as formerly. As
soon as methods of concentration have been
decided upon, the erection of the treatment
plant will be started and eventually it will be
enlarged to treat about 300,000 to 350,000 tons
of ore per annum. On this basis it is not un-
reasonable to say that the mine promises to
become the largest single lead-zinc-silver pro-
ducer in the world.

The Hargreaves-Bird electrolytic alkali
process, after many years of vicissitude, fol-
lowed by a drastic reconstruction of the com-
pany and change of control, is now being
worked at a profit, at Middlewich, Cheshire.