REPORT ON MINING DEVELOPMENT PLAN

OF

THE KABWE AREA

THE REPUBLIC OF ZAMBIA

MARCH 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

METAL MINING AGENCY OF JAPAN

FOREWORD

In response to the request of the Government of Zambia, the Government of Japan conducted a study of the development of the Kabwe area in the Central Province of the Republic of Zambia, and entrusted its execution to the Japan International Cooperation Agency. In view of the fact that the study belonged to a special field of investigation intended to probe into mine development, the Japan International Cooperation Agency consigned it to the Metal Mining Agency of Japan.

The study was carried out from December 1987 to February 1988, and was completed as scheduled with the close cooperation of the competent authorities of Zambia.

We wish to express our heartfelt gratitude to the Zambian agencies and organizations concerned and to the Ministry of Foreign Affairs of the Japanese Government and Japanese Embassy in Lusaka for the helpful support extended to the study.

March 1988

Kensuke Yanagiya
President
Japan International Cooperation Agency

Junichiro Sato
President
Metal Mining Agency of Japan

ACKNOWLEDGEMENT

This report presents the results of a study carried out by the International Development Center of Japan under commission from the Metal Mining Agency of Japan.

The objective of this study was to make a technical and economic evaluation of the existing condition of the Kabwe Mine in the Central Province of the Republic of Zambia, to conduct a comprehensive re-assessment of existing data on the exploration for lead, zinc and silver deposits in the Kabwe area, and thereby to propose a rational prospecting plan of the area.

It is my sincere hope that this study will contribute to the regional development of the Kabwe area and to the enhanced economic development of Zambia, while at the same time fostering the friendly relations existing between Zambia and Japan.

The members and schedule of the study team are shown in the attached sheet. I wish to express my heartfelt gratitude to the competent authorities of Zambia, the Japanese Embassy in Lusaka and the Zambia Office of the Japan International Cooperation Agency for the valuable assistance and guidance offered to the study team during its stay in Zambia.

My deep appreciation is also extended to the Ministry of Foreign Affairs of the Japanese Government, the Japan International Cooperation Agency, the Metal Mining Agency of Japan and other agencies and organizations concerned for the helpful support they offered to the team for smooth implementation of the study.

March 1988

Hideo Monden
President
International Development Center of Japan

ABSTRACT

For the purpose of further development of the Kabwe Area, re-assessment of the existing data on mineral exploration and mining has been made.

The area lies between latitudes 14°10' and 14°40'S and longitudes 28°05' and 28°35'E. The kabwe Mine is situated at about 140 km north of Lusaka.

Ore deposits of the former Broken Hill Mine occur in dolomites of the Katanga System, and were first discovered in 1902. Since the commencement of continuous production in 1915, some 10.5 million tonnes of ore grading at 25.4% Zn and 14.7% Pb were mined from seven massive orebodies of pipe-like structures. Ore reserves comprise silicate ore and sulphide ore, the latter of which will be exhausted within a few years if the rate of production is kept at the present level.

A number of employees at Kabwe mines and plants stands at about 1,800. Mining industry plays an important role in the local economy and also keeps inflow of foreign currencies to the country. Being a sole supplier of lead and zinc in Southern Africa, the operation should be maintained as long as possible.

The areas in the vicinities of the mine have been investigated from the turn of the century by means of geochemical, geophysical survey, pitting and drilling. Many anomalies were delineated and appropriately tested. Among them, a subordinate amount of copper ore was found in Sebembere and because of it, an intersected zinc mineralization in the adjacent area did not attract an attention until MINEX carried out the detailed geochemical survey and auger drilling programme at Kabwe West to reveal an existence of sulphide zinc in the overburden.

A survey programme is proposed to delineate the zinc mineralization in the bedrocks using diamond drilling and the reflection seismic method.

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SUMMARY

1. Introduction

A field survey was conducted for re-assessment of the existing data on mineral exploration and mining operation in the Kabwe area with a view to promoting the area's further development. The survey was carried out by the Japanese study team which left Japan on January 9, 1988, arrived at Lusaka on January 10, left Lusaka on January 29, and returned to Tokyo on January 31. An outline of the team's findings is introduced below.

2. Study Area

The study area lies between latitudes 14°10' and 14°40'S and longitudes 28°05' and 28°35'E. The Kabwe Mine is situated at a distance of about 140 km to the north of Lusaka. For convenience, the area can be divided into the following four blocks, from east to west, on the basis of exploration activities conducted in the past.

1) Kabwe Mining License area, which is the former Broken Hill Mining Area and the present Kabwe Mining Area
2) Chiwanda area
3) Kabwe West area, formerly covered by the Prospecting License of Sebembere
4) Lucali area, which covers the former Carmarnor Claims

3. Kabwe Mine

3.1 Ore Deposits and Reserves

Ore deposits at the Kabwe Mine were first discovered in 1902. The mine operation was initiated in 1906 after the Rhodesia Broken Hill Development

Company was formed in 1904, and its continuous operations started in 1915. Lead-zinc deposits occur in Katanga dolomites in the upper Pre-Cambrian, and seven ore bodies have thus far been exploited. Up to the present time, the mine has turned out a total of 10,500,000 tonnes of ores, consisting of 25.4% Zn and 14.7% Pb. Estimated ore reserves as of April 1, 1987 amount to 1,530,000 tonnes (17.5% Zn, 6.2% Pb), of which massive sulphide accounts for about 10%. It is expected that the mine's reserves will be exhausted in a few years if the mining operation is continued at the present level.

3.2 Mining and Mineral Processing

Mining operation is now carried out for a monthly production of 16,000 tonnes, comprising 13.2% T.Pb (5.3% S.Pb) and 18.8% T.Zn (7.2% S.Zn). Waste is separated by heavy media separation. Mine drainage amounts to slightly less than 50 m^3/min. Ores are processed by flotation to separate sulphide and oxidized ores. Sulphide is further separated to lead and zinc by the ISF, and oxidized ores are leached for recovery of zinc.

3.3 Infrastructure

Of the annual total production of 7,800 tonnes of lead and 22,200 tonnes of zinc, 5,000 tonnes of lead and 19,000 tonnes of zinc are transported to Dar es Salaam for export to overseas markets. Power demand at the mine is supplied by two private power plants (18 MW and 20.4 MW). The mine is linked with the national grid to meet an emergency power demand. Drinking water is obtained from wells and the upper part of the mine. Water required in the mining operation is drawn from the lower part of the mine.

The Kabwe area is provided with a complete set of welfare facilities, including company dormitories, hospitals, clinics, schools and recreational installations.

3.4 Financial and Economic Evaluation

The Kabwe Mine was operated with a government subsidy from 1981 to 1985, but its 1986 operation cleared a profit, though small in amount. It now has a total of 1,800 employees, thus ranking second only to the Zambia Railways (4,000 workers) in the Kabwe area. The mine produces an immense promotional impact on the regional economy, especially by providing employment opportunities for the local inhabitants, and is also an important source of Zambia's foreign currency earnings. Efforts should be made for preservation of the mine because it is the only source of lead and zinc supply in southern Africa.

4. Exploration in Kabwe Area and Vicinities

4.1 History

The vanadium deposits at Carmarnor 30 km to the west-northwest of Kabwe were discovered in the 1920's and were mined out. From 1925 through 1940, extensive prospecting activities were conducted by the predecessor of Anglo American Corporation.

Between 1953 and 1963, more than 25 localities were covered by the prospecting operations of Mineral Search of Africa, a subsidiary of Rio Tinto, and this was followed by the prospecting of eight places by Chartered Exploration Limited, a subsidiary of Anglo American.

In the meantime, copper deposits were discovered in the Sebembere area, and Geomin of Romania carried out exploratory drilling and tried to sink a prospecting shaft. In this area, exploration for zinc was later conducted by MINEX, and since that time the area has been called Kabwe West.

4.2 Prospecting Methods

Since the study area has a flat topography and its drainage system is not clear, the soil geochemical prospecting method has been used extensively over many years in the past. The Chartered Exploration Limited carried out the pitting work to trace the contact between Basement complex and Katanga sediments.

Geophysical prospecting has been performed using various new methods developed in the past, including the electromagnetic, gravitational, radiometric, IP, SP and magnetic methods, and drilling has been conducted in each anomaly zone detected by these methods, but no ore bodies have yet been discovered which can be exploited on a commercial basis.

4.3 Results of Prospecting

Auger or diamond drilling was conducted for each anomaly delineated by geochemical and geophysical prospecting, so that it is considered difficult to find a new, promising prospect in the study area. However, in the Sebembere area where the prospecting was conducted only for copper, the possibility of zinc mineralization was not explored until MINEX embarked on its field work.

5. Prospecting of Kabwe West

5.1 Geochemical Prospecting

Anomalous zones were delineated by the geochemical prospecting conducted in 1976 for the mineralized zone of zinc which was intersected by Rio Tinto, and auger drilling of 403 holes was carried out to determine the zinc distribution in the overburden. As a result, zinc values grading up to 30% were obtained and the existence of sulphide ore was also confirmed.

5.2 Geophysical Prospecting

The geophysical prospecting conducted also in 1976 in the Kabwe West area produced the data useful in substantiating and adding further to the geological information then available, indicating that the magnetic trend showed fair conformity with the aerial magnetic chart. In various geophysical prospecting tests made at the same time, the gravity anomaly measured with a worden gravimeter coincided with that obtained by geochemical prospecting, and the apparent resistivity obtained by the Schlumberger method served to determine the bedrock depths and dolomite distribution.

The adaptability of different geophysical prospecting methods can be summarized as follows.

1) The electric and electromagnetic methods are not fully reliable in prospecting for sphalerite and oxides having high electric resistivity, whereas the resistivity method is applicable in the survey of dolomite distribution.

2) The detailed gravimetric method makes it possible to prospect for the bedrock surface configuration and massive ore occurrences, but the influences derived from lithlogical variation, cavities and fissures should be taken into consideration.

3) Using the reflection method that has been recently developed, it is possible to explore the geological structure. If a reflection surface is found in dolomite, it can be interpreted to indicate an existence of ore deposits or cavities or fissures. The reflection method can also be used in measuring the depth to the bedrock.

5.3 Future Prospecting Plans

In the Kabwe West area where the existence of zinc sulphide in the overburden has already been confirmed, it is necessary to confirm its occurrence in the bedrock. Prospecting for this purpose should be undertaken at the earliest possible date because it is desirable to clarify the features of mineralization in the area while the sulphide processing facilities are in operation.

1) It is recommended that drilling be started immediately in the area lying on the northeastern side of Rio Tinto's finding where geophysical prospecting was implemented and high grade samples were obtained by auger drilling. Prospecting by the reflection method should also be planned for anomalous zones, including those in this area.

2) In the following year, prospecting should be continued in the above area and a drilling plan should be formulated for anomalous zones detected on the southeastern side of the area by geochemical prospecting, with the drilling locations determined on the basis of reflection prospecting data. For anomalous zones in the north, the geological structure should be made clear by means of the resistivity method or the detailed gravitational method.

3) When a mineralized zone is found, a drilling plan necessary for the ore reserve calculation or estimation should be worked out. If it is not found, the targets will be selected from anomalous zones delineated by geophysical prospecting.

I GENERAL STATEMENT

I GENERAL STATEMENT

1.1 Introduction

Pursuant to the request made by the Government of Zambia, the Government of Japan has decided to conduct a study of the re-assessment of existing data on mineral exploration and mining operation at Kabwe in the Central Province, the Republic of Zambia.

Accordingly, the Japan International Cooperation Agency and the Metal Mining Agency of Japan have been appointed to undertake implementation of the study in close cooperation with the authorities concerned of the Government of Zambia.

1.1.1 Objectives of the Study

The objective of the study is to undertake the re-assessment of existing data on mineral exploration and mining operation, aiming at the further development of the Kabwe Area.

1.1.2 Study Team

A study team comprising geologists, geophysicist, mining and civil engineers with personnels of the said agencies has been dispatched to undertake the study in cooperation with the staff of the Zambia Industrial and Mining Corporation Limited (ZIMCO), a parastatal holding company.

1.1.3 Counterpart

MINEX, Mineral Exploration Department of ZIMCO, started its activity in 1971. It was fully established as a department of Mining Development Corporation Ltd. and was called MINDEX. In 1978, MINDEX became a department of ZIMCO and was renamed MINEX as the only organization in the country specialised on general mineral prospecting and exploration. In 1988, MINEX has been placed under the management of Reserved Minerals Corporation Limited, a subsidiary of ZIMCO, but this re-arrangement does not seem to change the role and activities of MINEX.

1.1.4 Scope of the Study

The study shall be carried out from the view point of the mineral resources and existing mining operations.

(1) Re-assessment of existing geological, geochemical, and geophysical data.

1) Interpretation of relationship between mineralization and geological structure based on existing geological and drilling data

2) Statistic analysis of existing geochemical data.

3) Statistic analysis and interpretation of existing auger drilling data.

4) Interpretation of existing geophysical data.

5) Integrated consideration of existing data.

(2) Re-assessment of existing mining data

1) Re-assessment of ore-reserves based on the available reports and data.

2) Re-assessment of mining method and mineral processing.

3) Re-assessment of infrastructure.

(3) Establishment of the most appropriate survey program for the further mineral exploration project in Kabwe Area.

1.2 Study Area

1.2.1 Location and Access

The area of the present study lies between latitudes 14°10' and 14°40'S and longitudes 28°05' and 28°35'E. The Kabwe Mine is situated at latitude 14°27'S and longitude 28°26'E, some 140 km north of Lusaka on the Great North Road (Fig. 1-1-1). For convenience, the area can be divided into four groups of blocks, in which exploration works had been carried out in the past, from east to westward as

(1) Kabwe Mining Licence area,

(2) Chiwanda area, formerly covered by a Prospecting Licence,

(3) Kabwe West area, formerly covered by the Prospecting Licence of Sebembere, and

(4) Lukali area, which covers the former Prospecting Licence area of Lukali and also the Carmarnor Claims.

The Chiwanda Prospecting Licence, covering an area of 4,890 hectares, lies 5 km to the west of Kabwe between the former Broken Hill Mining Area and Sebembere Exploration Area.

The late Kabwe West area is approximately 17,000 hectares in extent with the centre situated about 20 km northwest of Kabwe. The area covers the former Sebembere Claims.

The Lukali Prospecting Licence covered an area of 47,268 hectares, lying some 25 km northwest of Kabwe and immediately northwest of the Sebembere Exploration Area. Within this area, a number of Carmarnor Claims existed, being some 30 km west-northwest of Kabwe.

1.2.2 Climate and Vegetation

The hot dry season of September to October has average temperatures in a

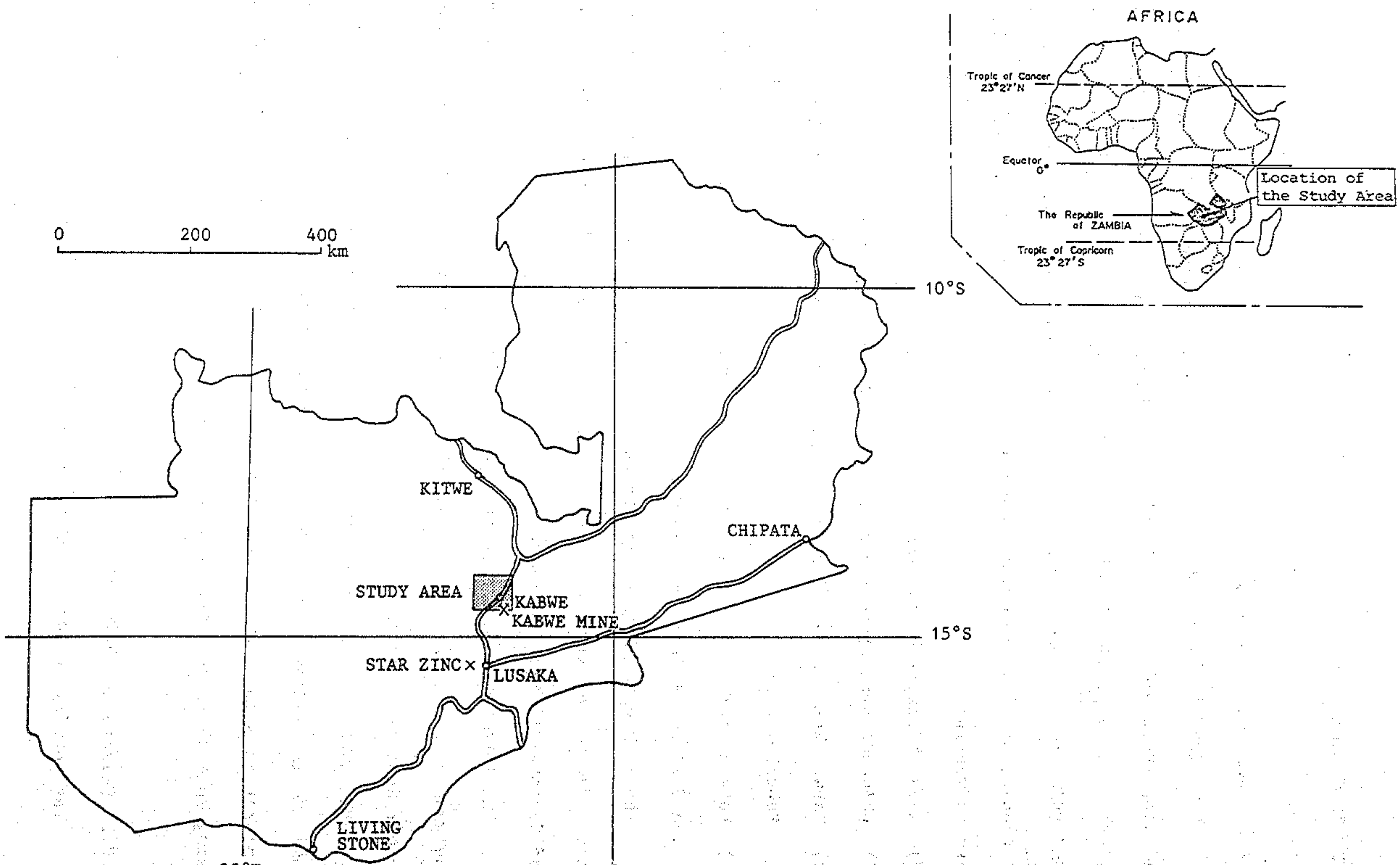


Fig. 1-1-1 LOCATION MAP

range of 30 to 33°C.

Average precipitation is on the order of 900 to 1,000 mm annually, most of which falls mainly in brief cloudburst from November to March.

The area is moderately timbered with shrubs, and is covered with coarse grass during the rainy season. Some of the woodland has been cleared for cultivation.

1.2.3 Geomorphology

The area lies on a flat plain at an elevation of 1,150 to 1,200 metres above sea level. Drainage is by dambos, only slightly below the level of the interfluves. The main streams flow either westwards into the Lukanga Swamps or eastwards to the Mulungushi River. The water table in the western part of the Lukali Area is reported to be not more than 2 m below surface, even in the dry season.

1.2.4 General Geology

The Kabwe area is very poorly exposed and only approximately 100 outcrops have been reported in nearly 4,000 sq.km. The geological succession is largely based on the results of regional pitting and diamond drilling.

The overall structure of the area comprises a south-westerly plunging antiform with a core of Basement granite gneiss and schistose rocks. The Basement is unconformably overlain by Katanga sediments of pre-Cambrian in age, which strike parallel to the Basement contact. The base of the Katanga System is often conglomeratic. Arkose and quartzites form a unit of variable thickness immediately above the base. Phyllite and dolomite unit consists dominantly of argillaceous dolomite and limestone, with beds of phyllite and clear crystalline dolomite. A lava or sill, described as an andesite or diabase occurs near the top of the unit. Massive dolomite unit has been reported at Carmarnor and in boreholes in Sebembere.

1.2.5 History

The area under the present study has been the site of intensive prospecting, since the discovery of the Broken Hill lead-zinc deposits at the turn of the century.

Ore deposits of the Kabwe Mine were first discovered in 1902. Lead and zinc carbonates were located on a prominent rounded hill or kopje. The mine was initially called Broken Hill after the lead and zinc deposits in Australia. The Rhodesia Broken Hill Development Company was formed in 1904 and export of zinc calcine was commenced in 1906 with the advent of the railway from the south. Continuous operations started in 1915 after commissioning a small blast furnace.

The lead-zinc-vanadium deposits at Carmarnor were discovered in the 1920's and the claims were acquired by Broken Hill Mine and worked for vanadium.

In 1925, prospecting rights over the part of the area north of 15°S were granted from the British South Africa Company, owners of all mineral rights in the country, to the Gold Fields Rhodesia Development Company and the Rhodesia Broken Hill Development Company, which formed Loangwa Concession (N.R.) Limited to prospect their area. The first regional geological investigations were initiated by this company. Later, control of both companies passed to interests controlled by the Anglo American Corporation. The Concessions terminated in 1940 and, apart from a number of small claims, the area was abandoned.

In 1953 and 1954, Rio Tinto were granted prospecting rights over the Rio Tinto Areas. Excluded from this grant were those areas held by Broken Hill Mine. Mineral Search of Africa, a subsidiary of Rio Tinto, explored some 25 separate sub-areas. In 1963, Rio Tinto relinquished the bulk of these areas, retaining only the Sebembere Copper Claims to the northwest of Broken Hill, which they retained an interest in until 1970.

The area was applied for and was granted as Chartered Area as from 1964. Excluded from this area were the Broken Hill Mineral Area and those claims held by the Rhodesia Broken Hill Development Company and the Sebembere claims retained by Rio Tinto. Chartered Exploration Limited, a subsidiary of Anglo American, commenced prospecting operations during the second quarter of 1964.

Chartered Exploration Ltd. continued exploration in eight different localities from 1964 till 1970. They traced the Basement-Katanga contact by detailed pitting, over most of its length within the area. The company became Zamanglo Exploration Ltd. in 1969.

Following the introduction of the Mines and Mineral Act of 1970, Zambia Broken Hill Development Company reduced their mineral area to a strip along the diagonal of their old areas and parallel to the mineralized dolomite belt, taking out a Mining Licence. Zamanglo relinquished their concession over most of the area, taking out only two prospecting licences, namely Lukali P.L. and Chiwanda P.L.. Pitting, geochemical analyses and diamond drilling were carried out in these areas until both were abandoned in 1972.

In 1970, Anglo American Corporation (Central Africa) Ltd. was reorganized as Nchanga Consolidated Copper Mines Ltd., when the Government acquired 51% holding in the company through the Mining Development Corporation (MINDECO). Zambia Consolidated Copper Mines Limited (ZCCM) was formed in 1981 as a result of the merger of the Nchanga Consolidated Copper Mines and Roan Consolidated Mines. MINDECO was subsequently absorbed into the Zambia Industrial and Mining Corporation Limited (ZIMCO).

In 1970, Geomin, the company for mining and geological cooperation of Bucharrest, Romania, was granted a Prospecting Licence at Sebembere and this was superceded by an Exploration Licence. Between 1970 and 1972, nine holes were drilled with a shaft to a depth of 37 metres. Early in 1975, Geomin and *MINDECO in partnership as the Mokambo Development Company* undertook further work for copper in Sebembere area. The programme entailed the drilling of five boreholes in the central zone of embayment. The Licence expired in 1975 (Fig. 1-2-1).

MINDEX, which was established in 1971 as a department of MINDECO, acquired a Prospecting Licence of Sebembere in 1976 for zinc. The Licence was named Kabwe West. The field works, including auger drilling of 403 holes of total depth 6,418 metres, were suspended in 1978. In this year, MINDEX became a department of ZIMCO and was renamed MINEX. As the absolute priority was given to exploration for fertilizer raw material, no work has been done since 1978 at Kabwe West.

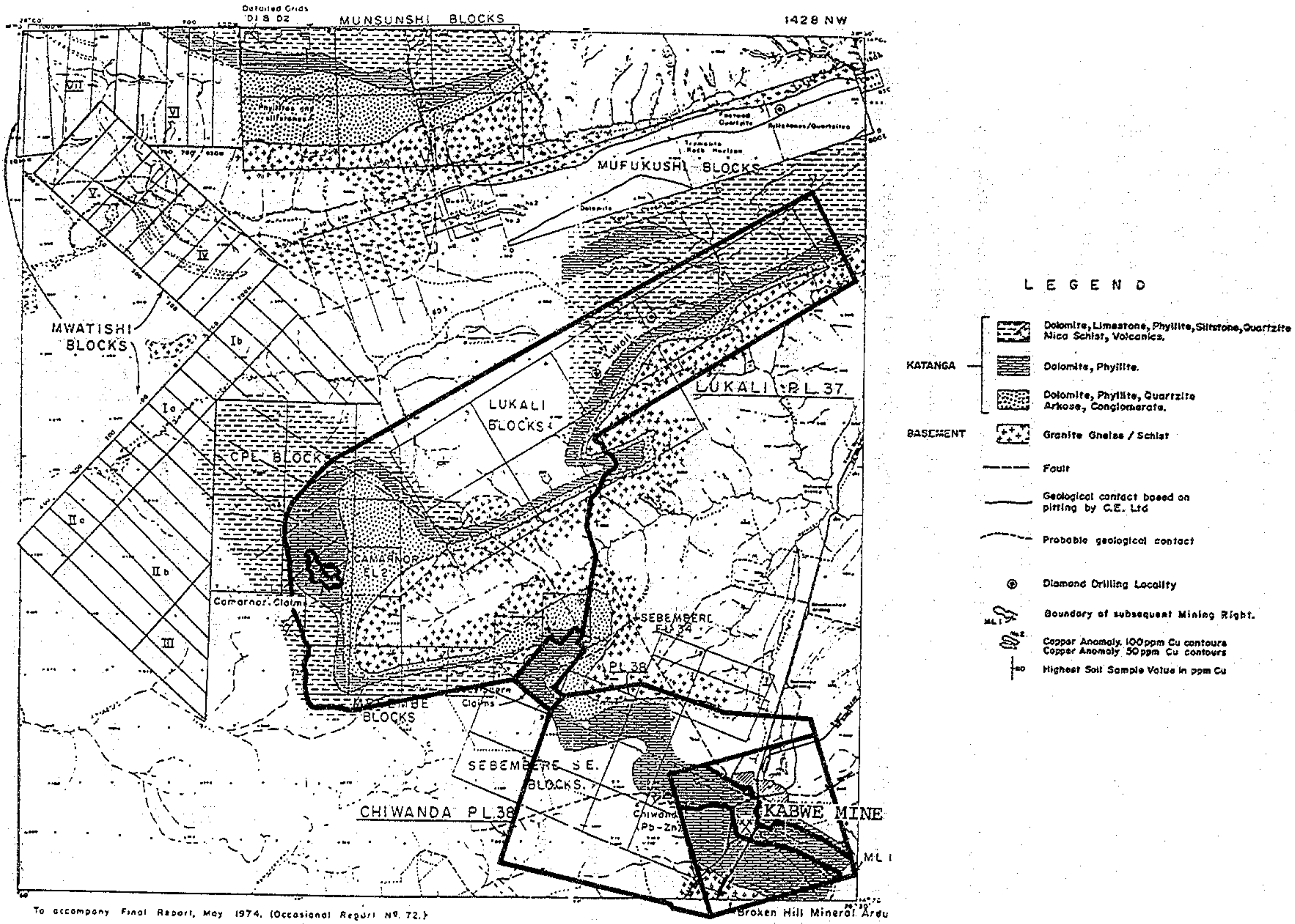


Fig. 1-2-1 Mineral Claims & Mining Rights in 1972

1.3 People Involved in the Study and Study Schedules

1.3.1 People Involved in the study

(1) Conclusion of S/W

<u>Japan</u>

MATSUKAWA, Yoshio	(Metal Mining Agency of Japan)
OKAJIMA, Kohji	(Ministry of International Trade and Industry, Agency of Natural Resources and Energy)
KITA, Yoshiyuki	(Japan International Cooperation Agency)

<u>Zambia</u>

R.L. Bwalya	(Executive Director, ZIMCO)
Nkata	*(Permanent Secretary, NCDP)*
J.H. Siwabu	(Legal Counsel, Group Corporation Secretary)
A.S. Sliwa	(Chief Geologist, MINEX)

(2) Study Supervisors

KOYAMA, Kyoichi	(MMAJ)
HIRANO, Hideo	(")
BABA, Yozo	(")
ADACHI, Naotaka	(")

Note) MMAJ: Metal Mining Agency of Japan

(3) *Study Team Members*

Leader	ONO, Takashi	(IDCJ)
Geologist	TOMIZAWA, Naoaki	(")
Geophysicist	SUMIDA, Harunobu	(")
Mining Engineer	KOJIMA, Kohji	(")
Civil Engineer	DOI, Masayuki	(")

Note) IDCJ: International Development Center of Japan

(4) Counterpart Team Members

RMC (Reserved Minerals Corporation Limited)

J.C. Vergeer	Managing Director

MINEX (Mineral Exploration Department)

A.S. Sliwa	Chief Geologist
L. Borsch	Chief Geochemist
D. Mulel	Senior Project Geologist
C.H. Muyovwe	Senior Project Geophysicist
E. Mbumba	Project Geologist
S. Simasiku	Project Geologist

ZCCM (Zambia Consolidated Copper Mines)

L.P. Mabson	Executive Director (Development)
P.V. Freeman	Consulting Geologist

Kabwe Division, ZCCM

F.R. Sakala	Mine Superintendent
M.M. Nyangu	Head of Finance and Supply
M.G. Downing	Mining Engineer
A. Le Roux	Resident Geologist
W.P. Faherty	ISF Superintendent
C.L. Milupi	Engineering Superintendent

1.3.2 Actual Schedule of the Study

Study Work Items	1987 December	1988 January	February	March
Preparation for the Study				
Study in Zambia		1/9~1/31		
Report Making in Japan				

1.3.3 Actual Schedule of the Study in Zambia

1/9	(Sat)	Tokyo 12:30 (JL401) 16:05 London 19:00 (QZ001)
1/10	(Sun)	Lusaka 6:40
1/11	(Mon)	Courtesy visits to the Japanese Embassy, JICA Zambia Office, and MINEX
1/12	(Tue)	Meeting with MINEX and analysis of the past study reports
1/13	(Wed)	Meeting with ZCCM and analysis of the past study reports
1/14	(Thu)	Courtesy visit to RMC and analysis of the past study reports
1/15	(Fri)	Analysis of the past study reports and preparation for the field survey to Kabwe
1/16	(Sat)	Trip from Lusaka to Kabwe and tour to Mita Hills Dam
1/17	(Sun)	Field survey to Kabwe West
1/18	(Mon)	Tour and interview in Kabwe Mine
1/19	(Tue)	"
1/20	(Wed)	Trip from Kabwe back to Lusaka and reporting to MINEX
1/21	(Thu)	Analysis of the past study reports and report manuscript writing
1/22	(Fri)	"
1/23	(Sat)	"
1/24	(Sun)	"
1/25	(Mon)	"
1/26	(Tue)	"
1/27	(Wed)	"
1/28	(Thu)	Tentative study results reporting to MINEX, the Embassy, and JICA
1/29	(Fri)	Lusaka 22:40 (QZ006)
1/30	(Sat)	6:25 London 19:00 (JL402)
1/31	(Sun)	Tokyo 15:50

II KABWE MINE

II KABWE MINE

2.1 Geology and Ore Deposits

2.1.1 Geology

The Kabwe Mine area is underlain by the Basement Complex of Pre-Cambrian and the Katanga System of late Pre-Cambrian. The Basement Complex consists of crystalline schists, gneisses and intrusive granites. The Katanga System is divided into the Lower Broken Hill Group of phyllites and the Upper Broken Hill Group of dolomites. The latter is further subdivided, from bottom to top into dolomitic shale, sandstone, conglomerate, shale-dolomite alternation (schistose dolomite) and massive dolomite. The massive dolomite, which is fine-grained, homogeneous, more than 280 m thick and bright whitish in color, is the host rock at the Kabwe Mine.

The overall geological structure was formed by two movements during the Lufilian orogeny (615-635 m.y.), which caused a gentle syncline plunging to the northwest and then a fold system gently plunging to the east-northeast. Later, a graben enclosing massive dolomite was formed by parallel faults trending in a north-south direction. Main ore bodies occur on the northern limb of the later fold in the graben (Fig. 2-1-1).

2.1.2 Ore Deposits

Originally seven outcrops existed and were numbered 1 to 7. It was subsequently shown that Nos. 3-4 and 5-6-7 formed only two distinct orebodies. Mining operation has been conducted on seven orebodies, including newly discovered ones, of No.1, No.2, No.3/4, No.5/6, No.8, E and X.

Six of them occur in a block of 1,000 m long in an east-northeast direction and 300 m wide with a depth to 500 m. The remaining No.2 orebody

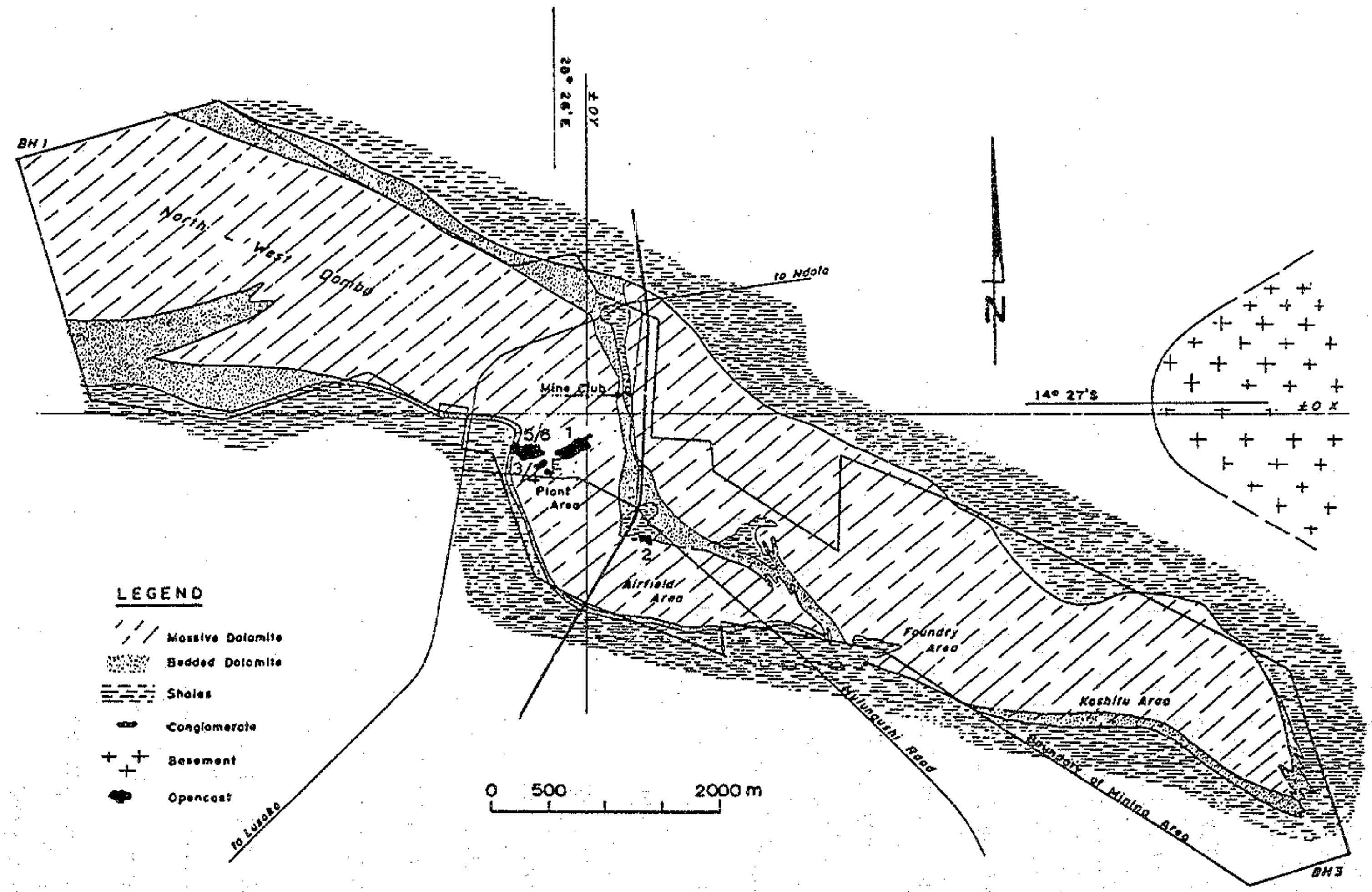


Fig. 2-1-1 Geological Map of Kabwe Mine Area
(After C.R. Kortman, 1972)

is situated about 700 mm southeast of the block. The orebodies in the block are massive and irregular and of pipe-like shapes, striking N65-75°E and dipping about 80°N with plunges of 30 to 50° to the northeast. Shapes on a level are elliptical. The largest orebody is No.5/6 having a strike length of 100 to 200 m and a width of 20 to 40 m, with a plunge of about 800 m long which extends from surface to the 1,650' level (about 500 m below the surface). Orebody No.2 has a form of steeply dipping bed along a contact between dolomite and shale, extending down to the 1,250' level (375 m below the surface) with an area of 100 x 20 m.

Orebodies consist of a primary sulphide core surrounded by a secondary oxidized zone. The oxidized zone ranges sub-constantly from 5 to 10 m in width, regardless of depths. Orebody No.2 has a width less than 20 m and is completely oxidized to the core. Sulphide minerals consist of primary sphalerite, galena and pyrite with very minor quantities of chalcopyrite and bornite. The gangue minerals are made up of dolomite and quartz. Pyrite was the first mineral to crystallize, followed by sphalerite and galena. No evidence of vertical zoning of sulphide ore minerals has been discovered. Oxidizd minerals consist mainly of willemite, smithsonite and cerussite. The texture of oxidized ore varies from massive to celluler. It presents brown color due to content of iron oxide. Vanadium minerals, descloizite etc., are concentrated in the outer zone of oxidized ore.

The contact between the orebody and the dolomite is distinct and brecciated zones or fissures are sometimes found along the contact. The massive dolomite is occasionally brecciated near the orebody. In most cases, brecciation is observed within 15 m from orebodies, especially above the ore. The dolomite fragments are angular, ranging in size from 1 to 50 cm across, and cemented by brownish lithic matrix. Due to the similarity between the matrix and the jasper-like lithified mud in the outer periphery of the orebody, the brecciation seems to have taken place at the same time and by the same process during the main oxidation of massive sulphide ores.

The isotopic composition of lead in galena from the massive sulphide ore gave an age of 712 m.y. The age is of the same order or slightly younger than that of dolomite sedimentation, but older than the age of Lufilian orogeny (615-635 m.y.). Ore genesis is to be considered that the metal elements were precipitated simultaneously with dolomite and subsequently mobilized by connant watwe from the sedimentation basin concurrently with local deformation to form the pipe-like massive orebodies.

2.1.3 Ore Reserves

The term of ore reserves covers ore reserves in situ and broken ore stored in ore blocks confirmed by two or more levels spaced within an 100 ft interval in height (30 m). The blocks are classified into three categories of "fully developed", "partially developed" and "undeveloped", depending on the progress of mining development. Since the ores have been mined downward from the top, remaining blocks exist at the lower most levels and on the ends of orebodies, and also in No.2 orebodies which have been oxidized.

Ore blocks in which more than 30% of zinc content come from oxidized zinc are grouped as of silicate ore and others are of sulphide ore. Grades of blocks are calculated by weighted averages of cannel sampling at an interval of 1.5 m, assayed for Pb, Zn, Fe and S. Since the boundary between orebodies and wall rocks is apparent and orebodies are very high in metal content, an idea of cut-off grade has not been introduced.

Specific gravities have been set at 4.5 for sulphide ore, 2.9 for oxidized ore and 2.8 for wall rocks in situ. Apparent densities stand at 3.4, 2.4 and 2.1 respectively for broken ores and waste.

Unclassified ore reserves such as reserves estimated by a single level or drilling are referred to as resources. They have been calculated in NO.2 orebodies, Old Airfield and Star Zinc prospects. Besides of these, there remain some pillars, which have not been calculated as ore reserves, at the middle of No.5/6 orebody and in the east of No.1 orebody, etc.

Ore reserves at 1st April, 1987 are:

Ore reserves (1,000 tonnes)

Silicate Ore	Sulphide Ore	Total
1,385	143	1,528
16.3% Zn	29.5% Zn	17.5% Zn
5.2% Pb	15.7% Pb	6.2% Pb

Resources (1,000 tonnes)

No.2 Orebody	Old Airfield	Star Zinc
369	3,573	218
10.7% Zn	3.0% Zn	19.7% Zn
1.5% Pb	--	--

2.1.4 Exploration

The exploration activity started in 1920's and has been intensified in the past several years due to a decrease of ore reserves. Exploration crosscutting and drilling have been implemented in the vicinities of mining area to delineate an extension of orebodies and to find out an existence of parallel orebodies. A sum of 6,700 m is to be drilled annually using two rigs of L-38. But new findings comparable with known orebodies have not been made.

The area has been covered systematically with the geochemical grids of soil sampling, and promising anomalous areas have been delineated in the area of dolomites. The Old Airfield prospect is located 1.5 km southeast of the mine and some 3.6 million tonnes of ore at 3% Zn, being of a disseminated and veinlet type of orebody, have been estimated by drilling of 26 inclined holes totalling 1,800 m in length, which was carried out in 1980. A deep hole is now being planned to investigate the the downward projection of the orebody.

At Foundry prospects at 6.5 km east-southeast of the mine, small orebodies of pipe-like structure have been located in dolomites and are being excavated. Gossanous outcrops at Mine Club in the east-northeast of the mine also have been planned to be drilled. The Kashitsu anomaly is known 5.5 km southeast of the mine.

The Star Zinc prospect is situated some 20 km northwest of Lusaka or 120 km southwest of Kabwe, being located 2 km west of the Great North Road, and has been mined by an open cut method in 1920's. Several holes have been sunk in recent years.

2.2 Mining

The Kabwe Mine was developed many years ago and open-pit mining was conducted in early days of its operation. Its underground structure indicates that the mine has been exploited in an intricate manner.

2.2.1 Production

At present, ores are being mined from the bottom and pillars of five ore bodies of Nos. 1, 3/4, 5/6, 8 and X and from ore body No. 2 which is entirely an oxidized ore body.

According to the production plan, the ore hoisted are about 13,000 tons/month, with 32,000 tons/month of waste derived from working faces and development galleries. The crude ore grade is 13.2% Pb (5.3% sulphide Pb) and 18.8% Zn (7.2% sulphide Zn).

Ores and waste are hoisted together to the surface and ores are separated from waste by heavy media separation.

2.2.2 Underground Structure

The configuration of ore deposits and mining facilities is shown in Figure 2-2-1 and Figure 2-2-2. The Ore Shaft and Davis shaft are located between ore body No. 5/6 and ore body No. 2.

The Ore shaft is a square type main shaft having five compartments, i.e., two for skips, two for cages and an auxiliary compartment with a small hoisting machine. It has been sunk to a 1,370' level below the ground surface and has four plats at levels of 550', 850', 1,050' and 1,250'.

The Davis shaft, sunk to a 1,580' level from the surface, is used mainly for drainage at present. Pump stations are installed at the plats of 1,058' and 1,585' levels of this shaft.

The shaft No. 1, located near ore body No. 1, is now used for

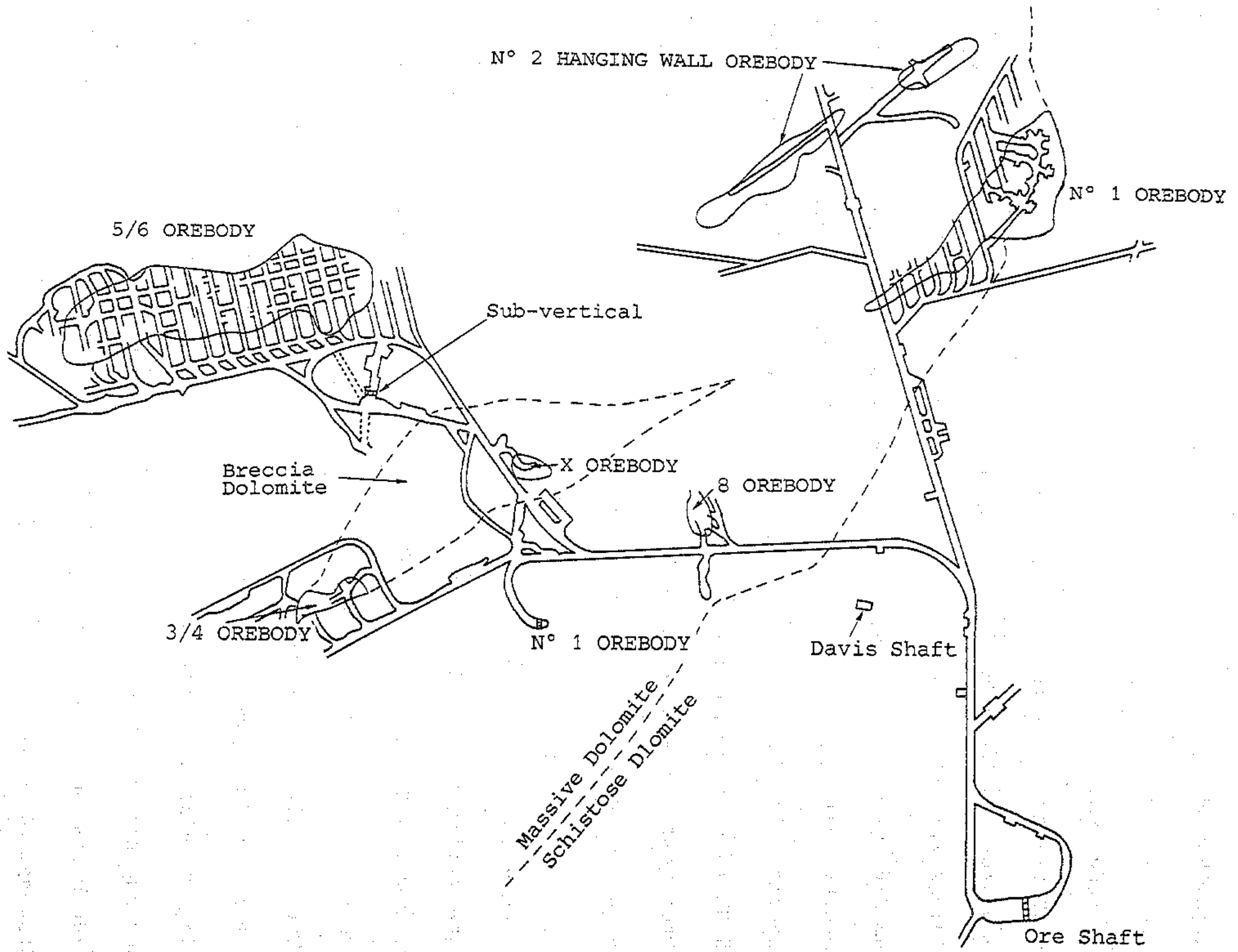


Fig. 2-2-1 Typical Mine Level Showing Ore Bodys & Mine Structure

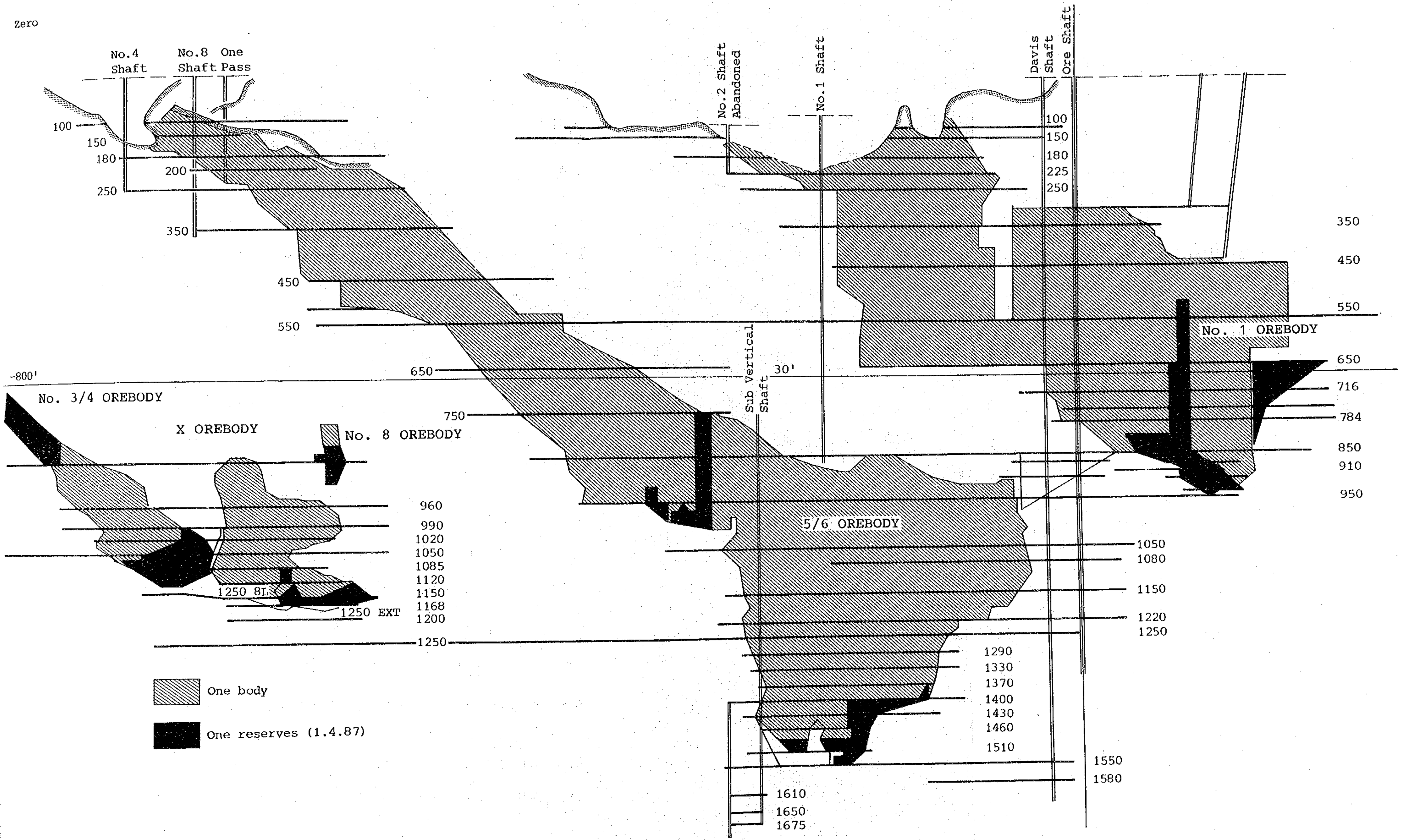


Fig. 2-2-2 Vertical Projection of Kabwe Mine

ventilation between the ground surface and the 850' level.

In the lower part of ore deposits, a sub-vertical blind shaft is excavated between the 850' and 1,650' levels, which is used for rock and man - winding in dual-purpose skips

Since the dolomite rock is very strong, all these shafts need no support except in the vicinities of the ground surface and plats.

Levels are opened up at an interval of 100' as shown in Figure 2-2-2. Drifts used at present have a cross-sectional area of 2.5 m by 2.5 to 4.0 m, and most of them have no timbering except in cavities in wall rocks.

Besides these, there are many inclined shafts, ventilation shafts, and rises opened for sub-level development.

2.2.3 Development

Development is carried out at a monthly rate of slightly less than 100 m, using hand-held jack hammers and rocker shovels. Explosives used for development are ammonium gelignite and dynamite.

2.2.4 Stoping

Stoping is performed by the sublevel open stoping method. In the standard, sublevels are driven at vertical intervals of 12 m and ores are mined at a strike length of 20 m, leaving a pillar of 10 m wide, and the gob pillars are removed later.

Ore are stoped by long-hole fan drilling using a bar-mounted pneumatic drilling machine. For blasting, ammonium gelignite and cordtex are used.

The gob is left as a cavity. Large cavities left in dolomite after stoping can be maintained because the dolomite host rock is extremely competent.

Most ore bodies except the oxidized ore body No. 2 have already been mined out, so that ores are now exploited from ore pillars, which require considerable time and labor.

In places where the loading level is directly connected to the tramming level, broken ores are loaded onto 2-ton ore cars at the draw point using a rocker shovel.

In other places, a raise is provided between the stope and the tramming level, and ores are scooped with a winch and scrapers installed between the raise and the draw point.

Ores dropped in the rasie are loaded onto the ore car with the loaded box provided on the tramming level.

Secondary blasting is required at the stope drawpoint to break up the over-size rocks and ammonium gelignite slabs are used for this purpose.

2.2.5 Mine Haulage

Ores and development waste loaded onto the 2-ton ore car are hauled by a 3-1/2- or 5-ton battery locomotive and thrown into ore bins of the Ore Shaft or sub-vertical shaft.

The ores thus thrown into the ore bins are loaded onto the skips at the loading point of the 1,310' level in the Ore Shaft and the 1,610' level in the sub-vertical shaft, and hoisted up to the ground surface or to the 850' level.

Table 2-2-1 shows an outline of hoisting machines used at the Kabwe Mine.

Table 2-2-1 Outline of Hoisting Machines

	Ore Shaft Compartments 1 & 2	Ore Shaft Compartments 3 & 4	Sub-vertical Shaft
Year of manufacture	1939	1939	1977
Purpose of use	Cage	Skip	Skip
Drive motor	600 HP	600 HP	175 HP
Volt	500 V DC	500 V DC	550 V DC
Speed	305 m/min	442 m/min	150 m/min
Maximum load	8,343 kg	8,750 kg	7,705 kg
Rope	LANG RH lay 36 m/m	LANG RH lay 36 m/m	LANG RH lay 28 m/m
Drum diameter	3.048 m	3.048 m	1.524 m
Guide	Timber	Timber	Timber

2.2.6 Drainage

The Kabwe Mine is in the same geological condition as the Copper Belt area which is known for the gush-out of voluminous underground water. Water gushing out in the underground amounts to a large volume, and it is pumped at a rate of slightly less than 50 m^3/min.

This mine water is drawn to the pump stations at various levels, i.e., the 1,085' and 1,510' levels of the Davis Shaft and the 1,675' level of the sub-vertical shaft.

It is then led to the pumping station at the 1,085' level of Davis shaft, from which it is pumped up to the ground surface and distributed for household and industrial uses.

Inside the Davis shaft are provided three lifting pipes of 20 inch diameter. Most of the pumps are West Germany.

2.2.7 Ventilation

The Ore Shaft and Davis Shaft are used for air intake and No. 1 shaft used for air exhaust. Some 6,000 m^3/min free air is taken into this system.

Since No. 1 shaft is linked with various places on the ground surface, most fans are installed at the 850' level of it.

A total of 8 units of fans with a capacity 1,200m^3/min are used, including those designated for local ventilation.

2.2.8 Operation

The mine operation is conducted in three shifts. Development and stoping are performed only in the day shift. Blasting is conducted at the end of the day shift.

Some 400 employees are engaged with the underground operation, comprising 230 of miners, 50 of attendants and 120 of personnels for maintenance and pumping operation.

As shown in Figure 2-2-3, the production per man, shift has been maintained at a level exceeding 2 tons/worker over the last few years. Considering the rather unfavorable condition under which the mine has been placed, this can be evaluated as a fairly high level.

2.2.9 Summary

The characteristics of the Kabwe Mine can be summarized in the following five points.

(1) Ore reserves have been reduced by years of continuous mining operation, and massive sulphide ores can now be exploited only from ore pillars or

other parts that entail considerable time and labor.

(2) The host rock is very competent, and provides great ease of development and stoping operation.

(3) Having been developed years ago, the mine is intricately exploited, and many of the mining facilities are outdated.

(4) The unit labor cost is rather low.

(5) Amount of underground water is very large.

Partly because of the declining ore reserves, efforts are made to make the best of the existing facilities to cut down the equipment investment.

For loading and hauling, small-type machines installed in early stages are still used to cut down the cost of consumable parts which are to be imported from abroad, and endeavors are made to take advantage of the firmness of host rock and low labor cost mentioned above. Since the productivity of the mine is maintained at a fairly high level by virtue of these efforts, it appears that there is no other way for the mine to pursue but to push forward the present policy.

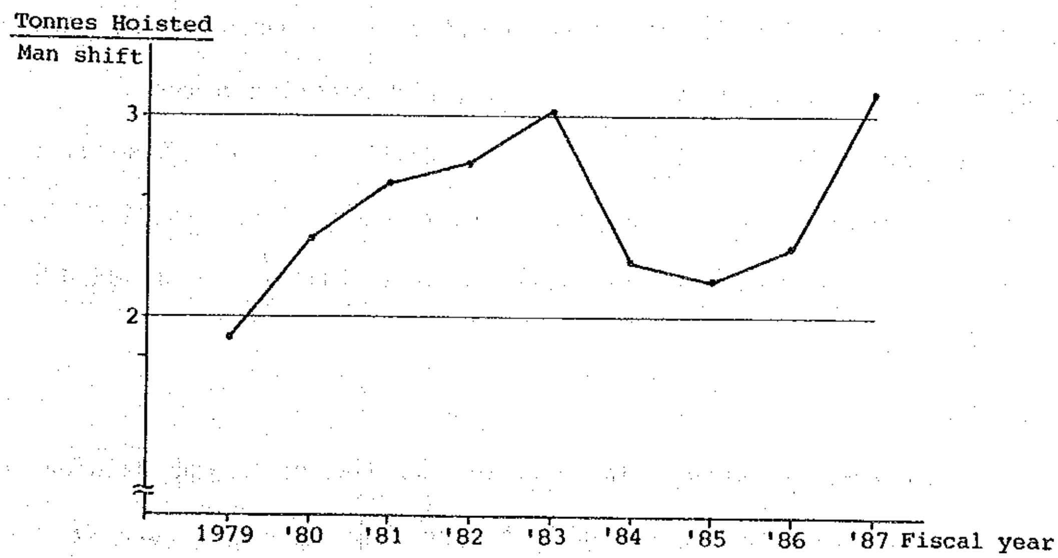


Fig. 2-2-3 Mining Productivity of Kabwe Mine

2.3 Mineral Dressing and Refining

2.3.1 Process

The mineral dressing and refining process adopted at the Kabwe Mine is shown in Figure 2-3-1.

(1) Washing and Heavy Media Separation

Ores containing waste, under 250 mm in size, are hoisted up from the mine and crushed to a size of less than 100 mm with a jaw crusher for washing and classifying.

Washed ore lumps ranging from 6 to 100 mm in size are separated into float and sink with a 2.5 m x 2.5 m drum using ferrosilicon fluid having a specific gravity of 2.9. The dolomite float is dumped at the waste yard.

The sink has a grade of 12.4% T-Pb, 4.4% S-Pb, 17.9% T-Zn and 4.6% S-Zn according to the 1987 production plan (all ore grade data in this section are based on this production plan). The sink is crushed with a 1.3 m cone crusher and a 2.4 m x 1.8 m ball mill until a 65% or more passes 325 mesh screen, and fed to the flotation line.

The washed fine is separated into mixed fine (3 to 6 mm in size) and washing plant slime (under 3 mm in size) with a dewatering screen.

The mixed fine (14.8% T-Pb, 7.3% S-Pb, 22.9% T-Zn, 12.5% S-Zn) is fed directly to the sinter plant, while the washing plant slime (16.2% T-Pb, 6.2% S-Pb, 15.2% T-Zn, 8.0% S-Zn) is condensed with a thickener and added to the feed for the flotation.

(2) Flotation

Ore fed to the flotating line consist of the sink and washing plant slime from the heavy media separation line and flotation tailings of earlier days (15.3% T-Pb, 5.9% S-Pb, 14.7% T-Zn, 5.7% S-Zn). These are separated into a lead concentrate (30.0% T-Pb, 21.8% S-Pb, 22.3% T-Zn, 15.4% S-Zn), a

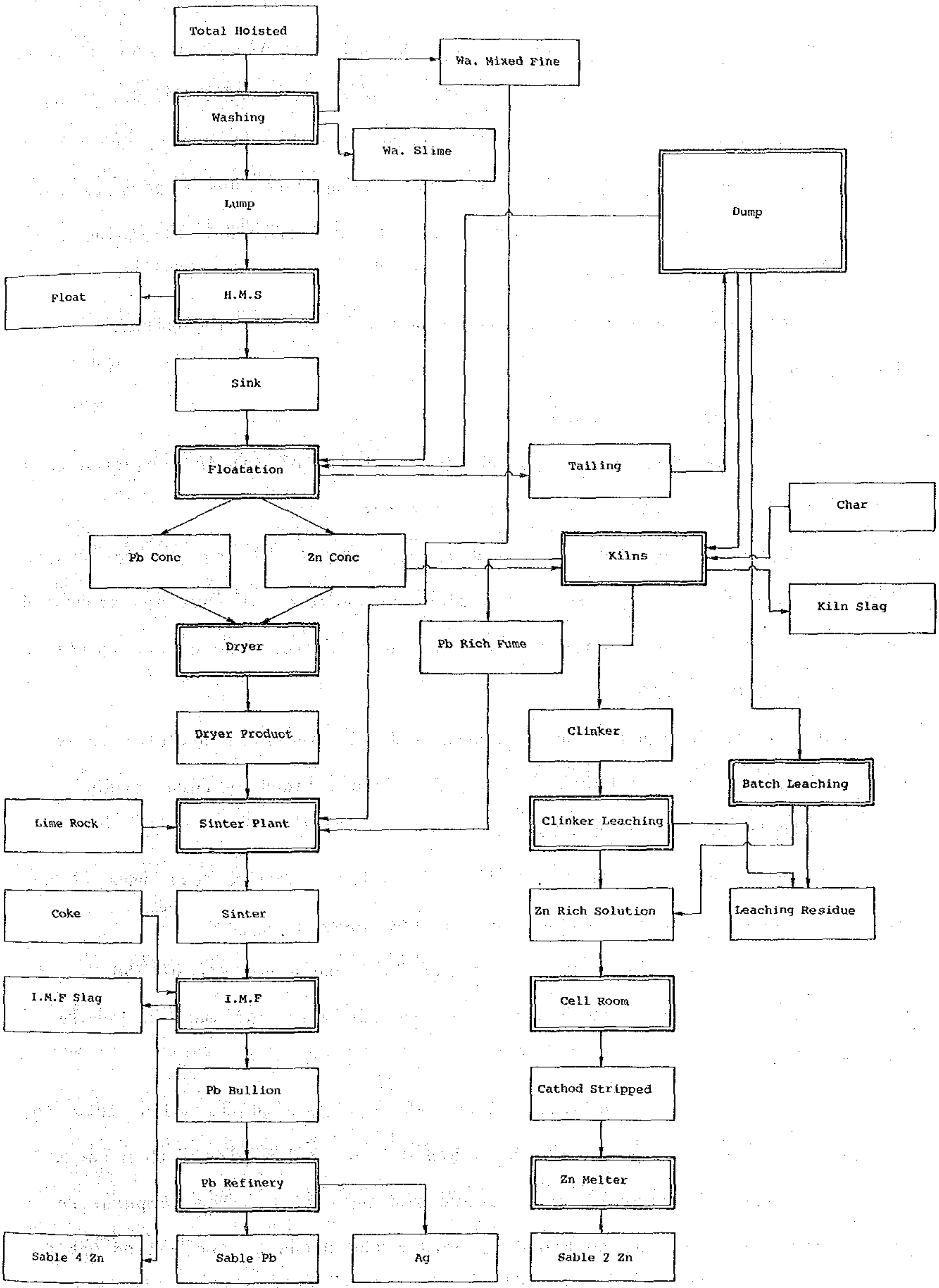


Fig. 2-3-1 Flow Sheet of Kabwe Processing Plant

zinc concentrate (7.8% T-Pb, 6.9% S-Pb, 45.0% T-Zn, 31.4% S-Zn), and tailings comprising mainly silicate ore (9.4% T-Pb, 0.5% S-Pb, 13.2% T-Zn, 0.7% S-Zn). The lead and zinc concentrates are thickened with the thickener, and formed into cakes with a disk filter. The lead concentrate and a part of zinc concentrate are fed to the dryer-sinter plant, and the remaining zinc concentrate is sent to the kiln.

Tailings thickened with the thickener are stored temporarily at the dumping yard.

(3) Zinc-Silicate Processing Line

A part of tailings of high grade (6.9% Pb, 18.8% Zn) is subjected to a batch type leaching using a high-speed agitator.

The low grade portion of tailings (3.5% Pb, 10.5% Zn) is heated with charcoal in a Waelz kiln, from which zinc is recovered as fume and processed in the clinker kiln together with the remainder of zinc concentrate to obtain clinker (2.3% Pb, 56.2% Zn).

The clinker is crushed and leached, and its zinc-rich solution is added to the solution from the batch-leaching line and refined by three steps.

(4) Electrolytic Zinc Plant, Zinc Refinery

The cell used at this plant is a lead-lined wooden cell made at the mine, and uses an aluminum cathode and a lead anode.

The cell is kept at a temperature of 36°C and a voltage of 258 V. The cathode is lifted every 48 hours to strip off zinc and make a bundle of recovered zinc.

The bundled zinc, weighing about 90 kg, is fed manually into the charging door of the furnace which is 5.8 m long, 3.7 m wide with a capacity of 120 t. Three batches of cathode are fed per shift. The temperature in the furnace is raised up to 650°C to obtain the product zinc called Sabld 2 after removing dross (46.2% Zn).

(5) Sinter Plant

The sinter plant is fed with the lead concentrate and zinc concentrate dried by the drier, mixed fine from the washing line, and lead-rich fume from the clinker kiln. They are mixed well with lime, pressed into pellets with a suitable moisture content and fed to the sinter plant.

The pellets are charged to a thickness of 300 mm onto the combustor which moves at a speed of 0.6 to 1m/min., and heated with an oil burner for sintering.

(6) ISF

The flow of the ISF (Imperial Smelting Furnace) process is shown in Figure 2-3-2.

The furnace consists of a reinforced steel casing lined with high alumina bricks, and its hearth lined with chrome-magnesite bricks. The furnace shaft is 9 m high from the hearth to the roof. The hearth is 7 m long and 1.55 m wide. Water jackets are equipped to the bottom of hearth with 18 tuyeres of 100 mm in diameter.

After the sinter (30.2% Pb, 28.3% Zn) is crushed by the claw breaker to a size of less than 90 mm, it is charged to the furnace from the top together with coke preheated to 600°C, and compressed air preheated to 650°C is blown in by a blower.

Zinc vapor and furnace gas are led to the condenser through the furnace off-take. When zinc is cooled down by the condensor, lead is removed from it in the condensation process to obtain the product zinc called Sable 2 zinc (1.2% Pb, 98.8% Zn).

On the other hand, lead bullion and slag are drawn out from the furnace hearth, and lead bullion is sent to the lead refinery.

(7) Lead Refining

The lead bullion from the ISF (93.3% Pb, 1.3% Zn) is processed by three

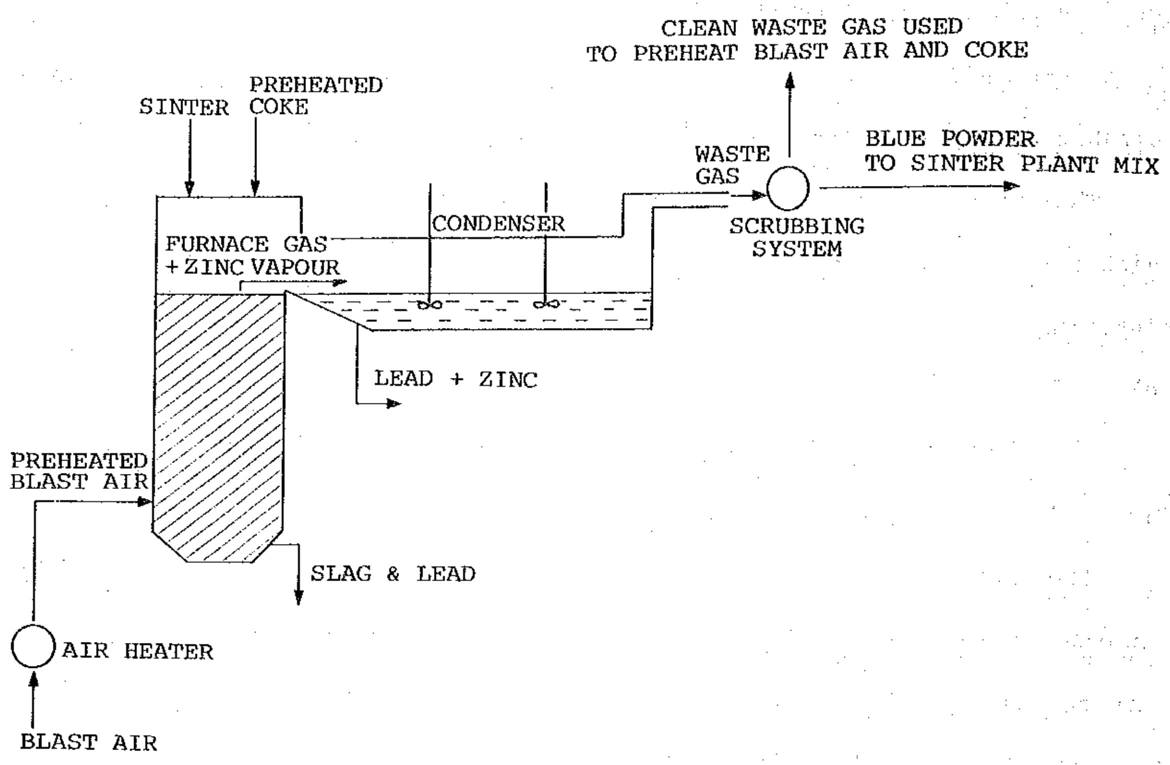


Fig. 2-3-2 Flow Sheet of Imperial Smelting Furnace

stages of decoppering, desilverizing and dezincing, whereby the product lead called Sable lead is obtained. In this process, silver contained in the lead bullion is recovered as the product silver.

Besides the metal processing lines outlined above, the concentration and refining operation at the Kabwe Mine includes many other repetitive processes which are quite complex as shown in Figure 2-3-3.

2.3.2 Summary

As described above, the metal recovery system adopted at the Kabwe Mine is made up of a number of complex concentration and refining processes. This is because the system has been modified year after year to make it compatible with the following characteristics of ore deposits exploited at the mine.

(1) Ore deposits comprise approximately 50% each of massive sulphide and silicate.

(2) When dolomite is removed by heavy media separation, the gangue mineral content other than sulphide and silicate can be reduced to a very low level because of the very high ore grade.

(3) Lead and zinc can be fed to the plant at a stabilized ratio of about 1:2.

Accordingly, in order for the plant to maintain the present level of operation, it is considered preferable to find new, high-grade ore bodies with a Pb/Zn ratio of about 1/2 containing nearly 50% of sulphide similar to the orebodies Nos. 1 and 5/6 that have been the mainstay of the mine operation in the past.

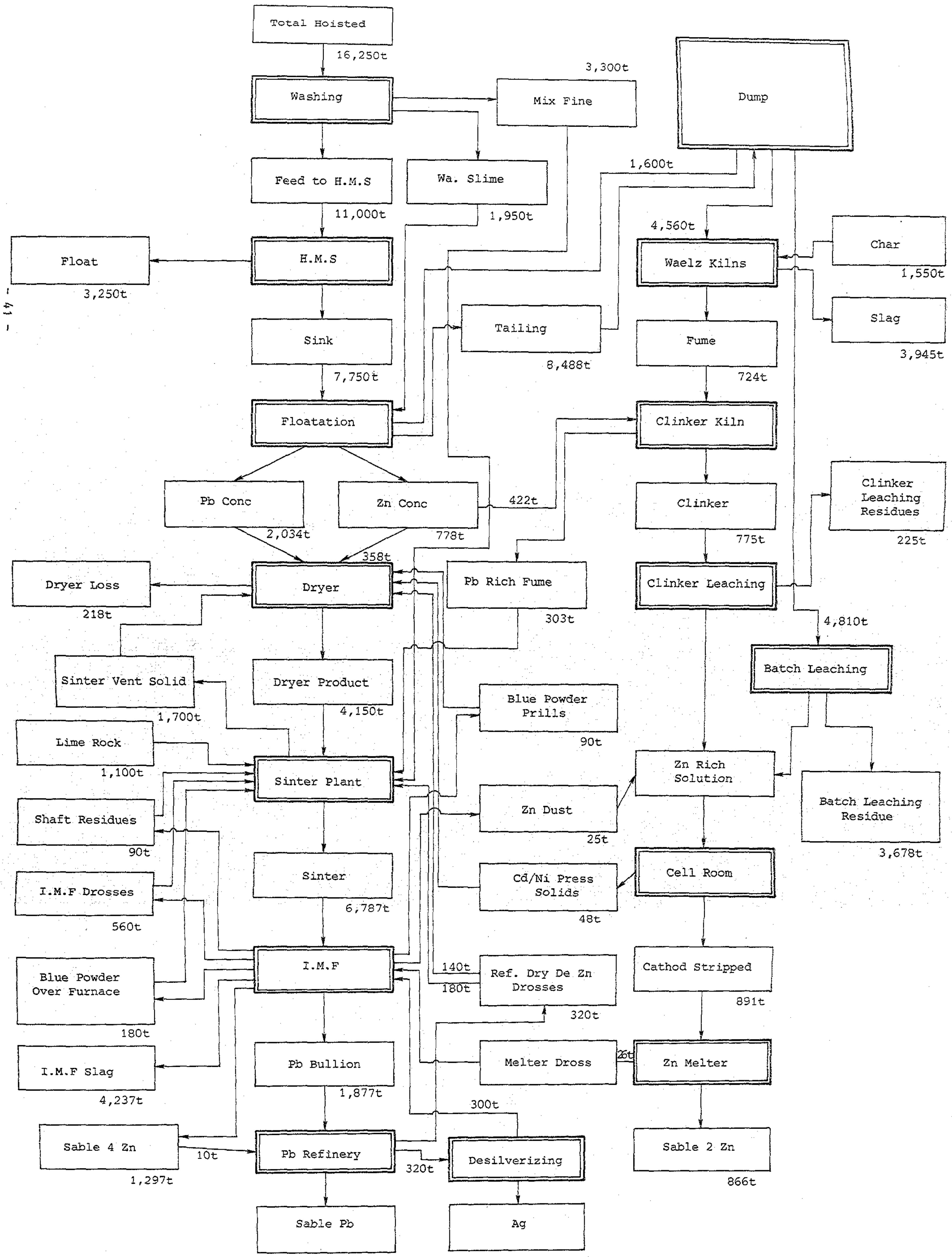


Fig. 2-3-3 Detail of Plant's Flow Sheet
(From Production Estimated 1987)

89.6.12
情報管理課

国別プロジェクト概要入力用シート

1. 国（地域）コード： 2 8 3 0

2. 分野別分類コード： 4 0 1 0 1 0

3. プロジェクト番号： 3 3 6 2 0 0 6

4. プロジェクト名： Kabwe Area / Zambia

5. プロジェクト段階： 2

6. 担当機関（部課）： 2 3 0 3

（注釈一覧）： Mining Development Plan

（注1）4．プロジェクト名：和文プロジェクト名の場合は、注釈一覧に表示。
（注2）5．プロジェクト段階は、1．選定・確認、2．準備・形成、3．審査・承認、4．実施、5．実施後の5段階とする。
（注3）6．担当機関（部課）：JICA担当プロジェクトの場合は、担当部課コードを記入。

表紙, Abstract, P1～18

2.4 Infrastructure

2.4.1 Transportation

The transport demand of the Kabwe Mine in the 1986/1987 fiscal year was as shown in Table 2-4-1, which indicates that a total of 30,000 tonnes of metal was carried out of the mine in that year. Railways play the central role in meeting this metal transport demand.

Table 2-4-1 Metal Transport Volume (1986/1987)

(unit: tonne)

Lead	Exports	Dar es Salaam route	5,000
		Zimbabwe	800
	Domestic consumption		2,000
	Subtotal		7,800
Zinc	Exports	Dar es Salaam route	19,000
		Zimbabwe	2,000
	Domestic consumption		1,200
	Subtotal		22,200
Total			30,000

Source: Kabwe Mine, ZCCM.

Railway services in Zambia are run by two different operators. One is Zambia Railways Ltd. (ZR) and the other is Tanzanian-Zambia Railways Authority (TAZARA). The ZR's service covers a total route length of 1,273 km comprising the 848-km trunk line, linking Victoria Falls Bridge in the south and the Copper Belt zone, and a branch line network connected to it (425 km). The TAZARA covers a total route length of 1,850 km consisting of the 880-km line operated in Zambia between Kapri Mposhi Station of ZR and Tunduma on the

Tanzanian boarder and the 970-km section extending from Tunduma to Dar es Salaam in Tanzania. The ZR and TAZARA have a track gauge of 1,067 mm and are mutually using each other's tracks.

The ZR stops over at Kabwe. The Dar es Salaam route shown in Table 2-4-1 connects Kabwe with Kapri Mposhi and extends farther to Dar es Salaam by the TAZARA line (Fig. 2-4-1). The rate along this route is K24.72 per tonne in the Kabwe - Kapri Mposhi section and K211.56 per tonne in the Kapri Mposhi - Dar es Salaam section. Accordingly, the metal transportation cost by the Dar es Salaarm route amounts to K5.67 million.

Main materials and equipments, transported to the mine are coal, coke, limestone, sulfuric acid, fuel oils, and machine parts. These are supplied mainly by the railways and partly by roads. Annual total transport volume amounts to 104,500 tonnes, of which 30,000 tonnes are accounted for by coal, 24,000 tonnes by coke, 30,000 tonnes by limestone, 12,000 tonnes by sulfuric acid, 3,500 tonnes by fuel oils, and 5,000 tonnes by machine parts.

The Kabwe area is not just covered by ZR's service, but has the ZR's headquarters located in it, so that enjoys convenience of various kinds. For example, ZR's sidings extend into the Kabwe Mine to make the loading operation easy, and its marshalling yard is also located near the mine.

Since the mine uses mainly the railway service for transportation of metals and materials, it owns a very limited number of vehicles, which include 16 passenger cars, 14 of 7-tonne or 10-tonne trucks, 33 pick-up trucks, and a number of other vehicles for mining operation such as forklifts and cranes.

In case a new ore deposit is discovered in the Kabwe West area or its vicinity and mining operation is to be started, it is likely that a trucking company will be hired if the transport volume is small. At present, the rate of trucking amounts to K0.91/tonne.km for short-distance haulage service and

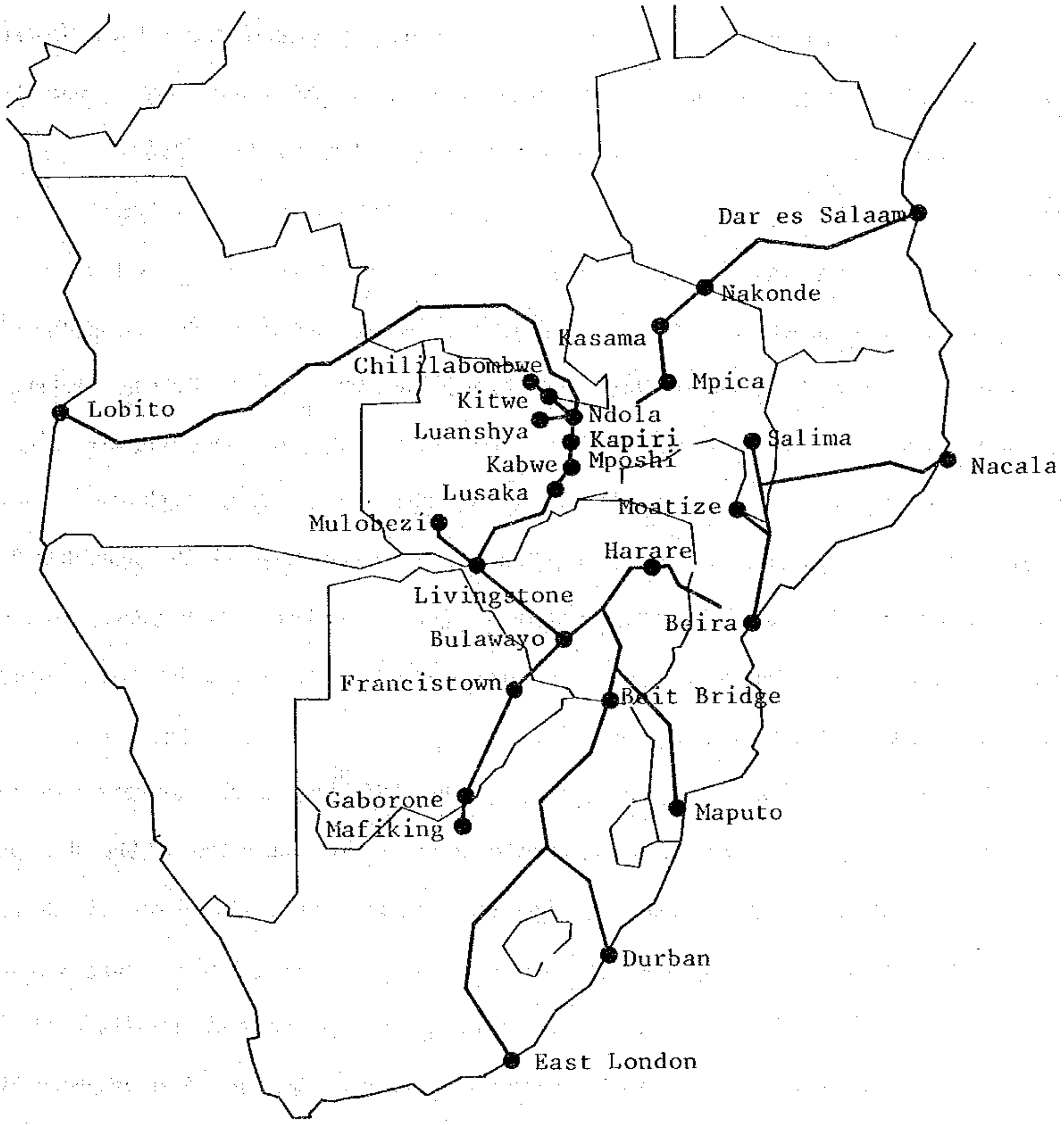


Fig. 2-4-1 Railway Network in and around Zambia

to K0.55/tonne.km for long-distance service. If the transport volume is large, however, it is probable that the mine will procure the necessary number of vehicles and set up its own transport service system.

As for telecommunication service, the mine is linked with four lines of the country's telephone service network, and with 24 local telephone lines covering in the mine area and the neighboring residential districts.

2.4.2 Electric Power

The maximum power demand at the Kabwe Mine is 30 MW. Power consumption registered 16,136,000 KWH in December 1987, and the annual total consumption in that year was 141,198,600 KWH. This power demand is supplied by two private hydro-power plants owned and run by the mine. One of them, Lunsemfwa Power Station, was built in 1945, and the other, called Mulungushi Power Station, was built in 1927. The power system comprising these two plants is linked with the nation-wide transmission network called the National Grid to provide for an emergency power demand.

The Lunsemfwa Power Station is located 100 km northeast of the Kabwe Mine and makes use of the water-power resources of the Mita Hills dam built on the Lunsemfwa river. It has a maximum supply capability of 18 MW. The maximum power demand in December 1987 was 16.9 MW, and power consumption in that month was 10,181,000 KWH. The average power demand is 13.6 MW, but power demand rises slightly in the rainy season to pump up mine water. There is a 66 KV transmission line (C line) linking this plant with the Mulugushi Power Station.

The Mulungushi Power Station is situated about 60 km east of the Kabwe Mine and uses the water-power from the Mulungushi dam on the Mulungushi river. It has a maximum supply capability of 20.4 MW. The maximum power demand in December 1987 was 14.6 MW, and power consumption in this month was

5,955,000 KWH. Power demand averages 8.0 MW and increases slightly in the rainy season. This power plant is linked with the Kabwe Mine by two 66-KV transmission lines (lines A and B).

The power system comprising these transmission lines is linked with the National Grid by one of the two lines (line B) at a distance of 20 km from the Kabwe Mine (Fig. 2-4-2). The National Grid consists of three major hydro-power plants which are the Kafue Gorge Power Station, the Kariba North Power Station and the Victoria Falls Power Station. Zambia is self-sufficient in power supply, and exports one third of its total power output to Zimbabwe. The National Grid is operated by the Zambia Electricity Supply Corporation (ZESCO).

A trial calculation indicates that if the 1987 total power demand at the Kabwe Mine had been supplied by the National Grid, the power cost would have amounted to K0.052/KWH, although the accuracy of this calculation cannot be checked because the ZESCO's power rate system is divided into three parts. Compared with this, the cost of power generation at the two plants owned by the Kabwe Mine is as low as K0.005/KWH, and the annual maintenance cost of each plant amounts to no larger than K70,000. The availability of a stable power supply at low cost is one of the features of the Kabwe Mine.

Rainfall in Zambia is concentrated in the November - April period, and the country is arid through the remaining period of the year. Annual rainfall shows regional differences. It registers more than 1,000 mm in the northern highland area and decreases gradually toward the south, recording about 900 mm in the Kabwe area and vicinities.

If a new ore deposit is discovered in the Kabwe West area and its mining operation is to be started, it will be necessary to extend transmission lines from the existing power system. It may be added, for reference, that the construction cost of an 11-kV transmission line amounts to K1.5 million per

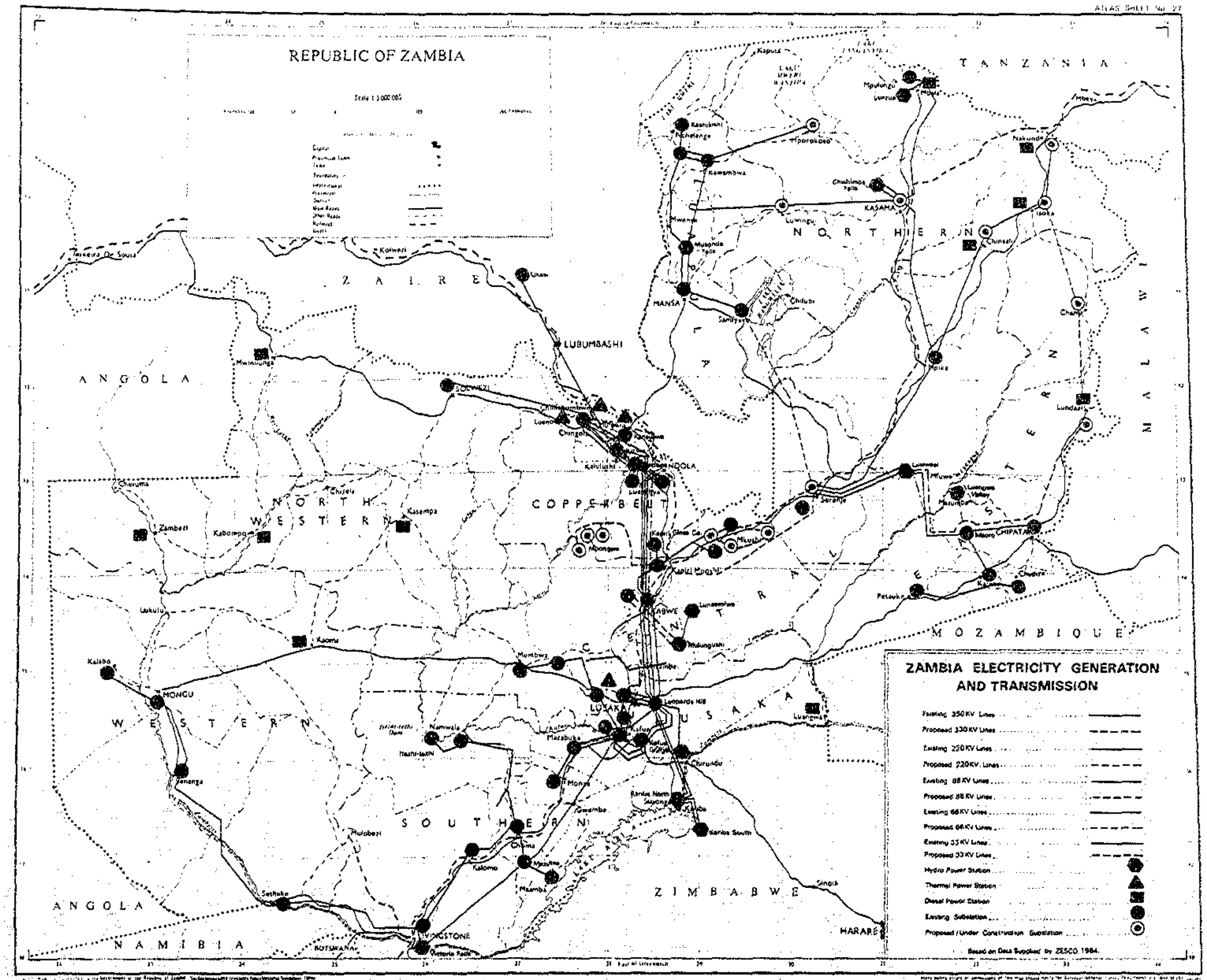


Fig. 2-4-2 National Power Generation and Transmission Network of Zambia

10 km.

2.4.3 Water Resources

Water resources need to be secured to supply drinking water to the mine area and the neighboring residential districts as well as water required for ore dressing and other mining operations.

For supply drinking water, underground water is pumped up from boreholes and mine water is also pumped up from a 550-ft. (168 m) level under the ground surface. There are about 20 boreholes, and a half of them are used for drinking water supply. Table 2-4-2 shows the volume of water pumped up. Water thus pumped up is purified by the chemical treatment process and supplied as drinking water to the mine and residential districts.

For supply of water needed for ore dressing and other mining operations, mine water is pumped up from a 1,700-ft. (519-m) level at rates of about 91,000 m^2/day at the maximum and about 60,000 m^2/day on the average. Since this mine water is at a level lower than the led ore deposits, it cannot be used for drinking and cooking purposes.

Rainfall in the Kabwe area, described already in the preceding section, poses no specific problems in securing water resources for the mine and residential districts.

Table 2-4-2 Drinking Water Pumped Up from Underground Levels

(1986/1987)

Borehole	Underground level (m)	Water volume (m^3/year)
W2	33.9	18,340
W4	42.5	30,594
W5	45.0	10,592
W7	-	58,992
W8	48.4	145,994
W9	39.4	23,370
W10	41.7	55,734
W15	32.0	-
W19	38.0	12,903
550'-level mine water	167.8	44,334
Total		400,853

Source: Kabwe Mine, ZCCM

2.4.4 Urban Facilities

As of the end of November 1987, the Kabwe Mine had a total of 1,800 staff members and mine workers. Urban facilities for these workers are fairly well developed, all owned, operated and maintained by the mine.

As for housing facilities, there are three townships developed for different income-groups, i.e., the high-income group township, the middle-income group township and the low-income group township, which are all located within walking distance to the mine. The high-income group township accommodates 433 houses, each having three to four bedrooms and covering a plot area of about 2 acre (4,047 m^2). The middle-income group township accommodates 632 houses, each having two or three bedrooms and covering a plot area of about 1/4 acre (1,061 m^2). The low-income group township accommodates 1,039 houses, each having two or three bedrooms but covering a rather small plot area. Accordingly, houses in this township are built close to each other.

If a new ore deposit is discovered in the Kabwe West area and the number of workers is increased as a result of mining operation, it is likely that housing construction will be undertaken in the area. The cost of housing construction, including the facilities installation cost, now amounts to K2,000 per one square meter of floor area. If no housing construction is undertaken, the mine workers will be transported from the existing townships by bus service.

The hospital in the Kabwe residential district is staffed by four doctors and has 84 beds. As for educational facilities, a primary school and a secondary school is established in the area. Other urban facilities in the area include the following.

1) Golf course (18 holes)
2) Rugby field
3) Squash club
4) Tennis court
5) Social club (incl. swimming pools)

2.5 Economic Evaluation

2.5.1 Financial Analysis of Kabwe Mine

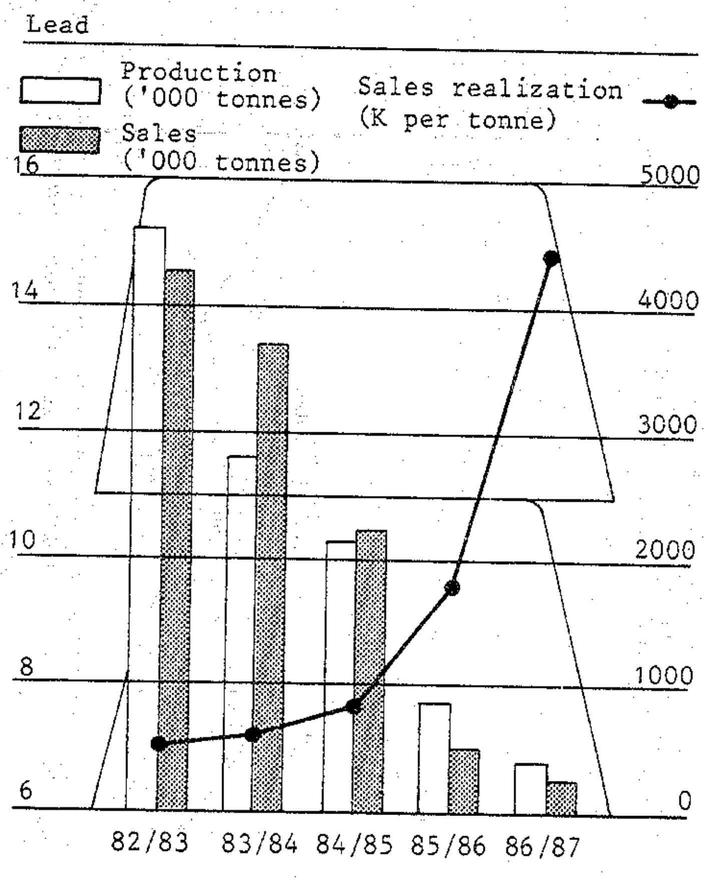
Figures 2-5-1 and 2-5-2 show the changes in annual production of lead and zinc, respectively, and Figures 2-5-3 and 2-5-4 indicate the changes in annual quotations of lead and zinc, respectively, at the London Metal Exchange. Owing to a decrease in output and the sluggish international metal market, the Kabwe Mine has been faced with a stringent financial condition in the last few years.

The financial statement for the business period ending in March 1987 shows total sales of K28.9 million and total expenses of K56.6 million for lead, with a deficit amounting to K27.7 million. As for zinc, total expenses amounted to K204.2 million as compared to total sales of K134.8 million, thus registering a deficit of K69.4 million.

The total expenses mentioned above include a depreciation expense amounting to K20.3 million for lead and K66.0 million for zinc.

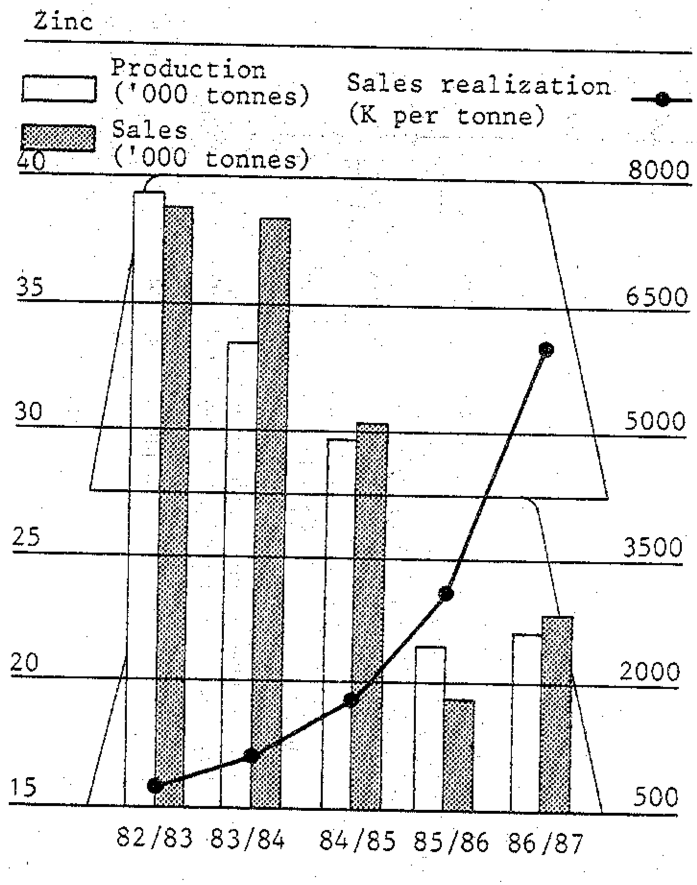
The phenomenal increase in the depreciation expense from the level a few years before was caused by the re-evaluation of assets made inevitable as a result of the Kwacha's sharp depreciation in recent years (Depreciation expense in the 1981/1982 fiscal year amounted only to K1.7 million for lead and K4.6 million for zinc). Accordingly, if the cash flow is reviewed with the depreciation expense left out of consideration, it can be seen that an operating income of K3.3 million was gained in the 1986/1987 fiscal year even if capital spending is included, and this indicates that the mine's performance in that year was close to the break-even point.

The Kabwe Mine's financial standing began to pursue a downtrend from around the 1981/1982 fiscal year. From this year through the 1985/1986 fiscal year, the mine was operated with a government subsidy. The subsidy



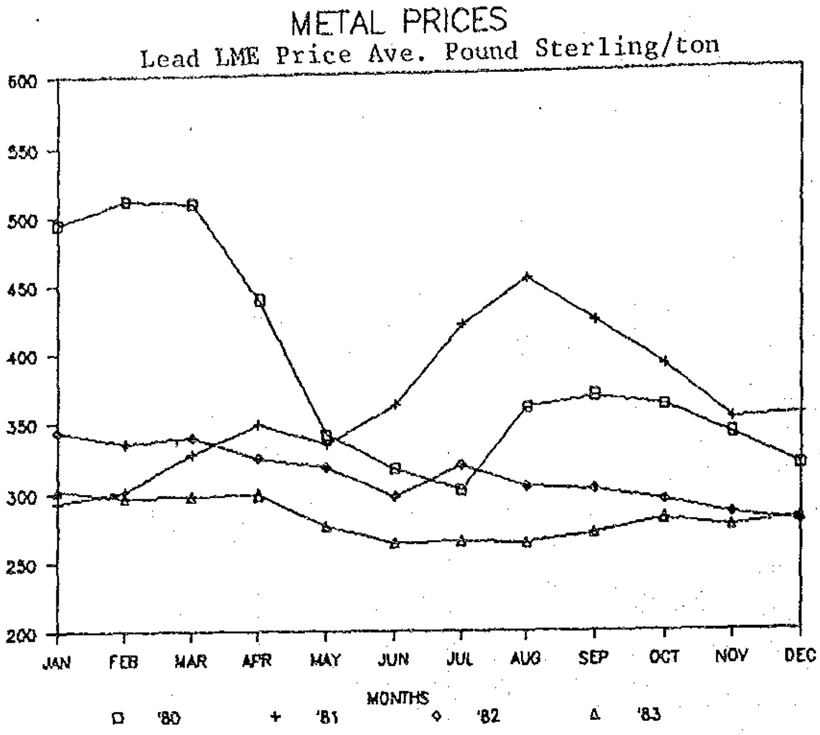
Source: ZCCM 1987 Annual Report.

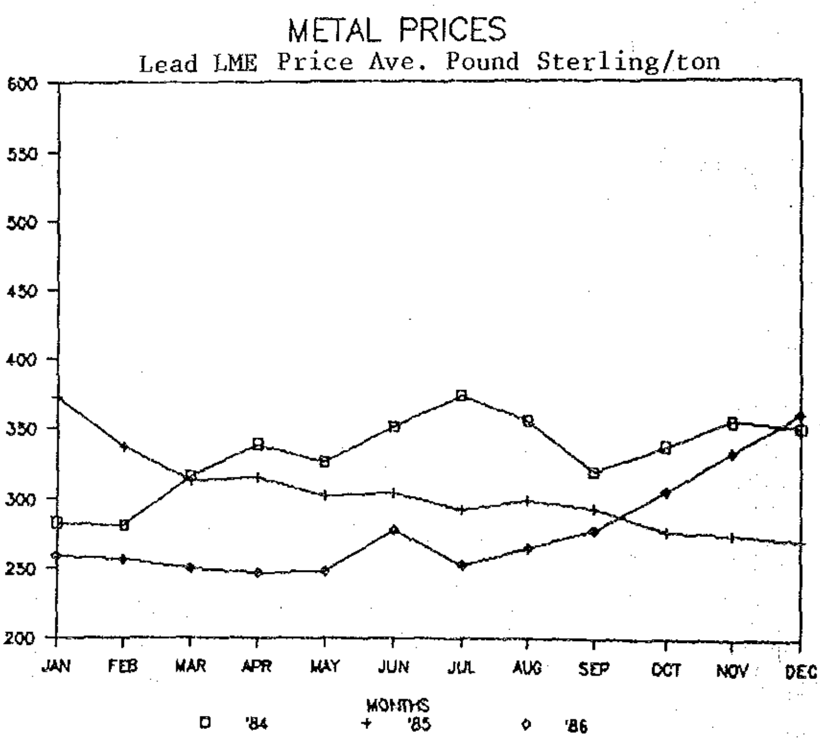
Fig. 2-5-1 Production Trend of Lead



Source: Same as Fig. 2-5-1.

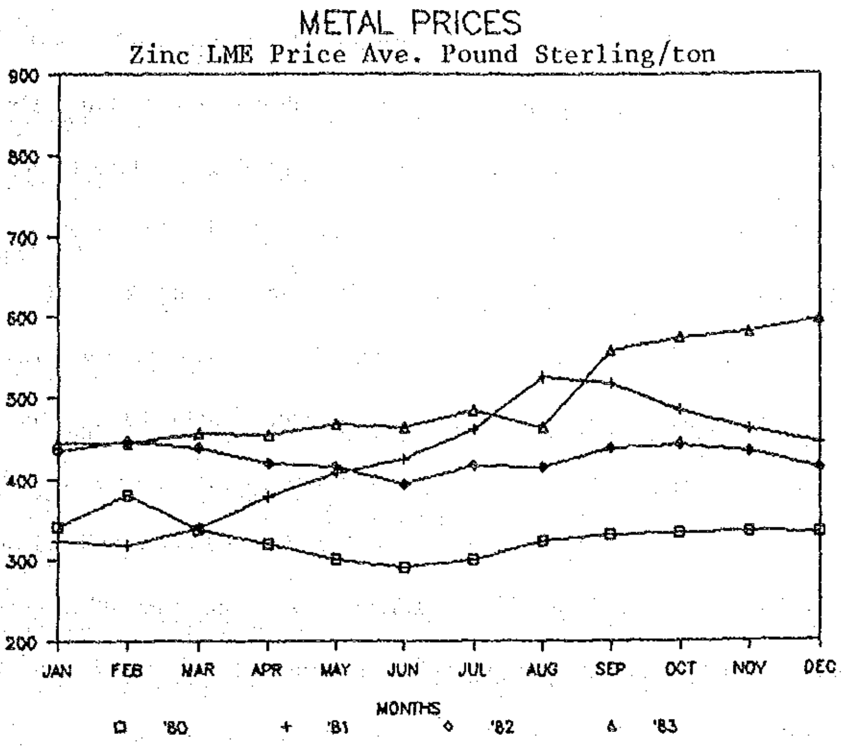
Fig. 2-5-2 Production Trend of Zinc

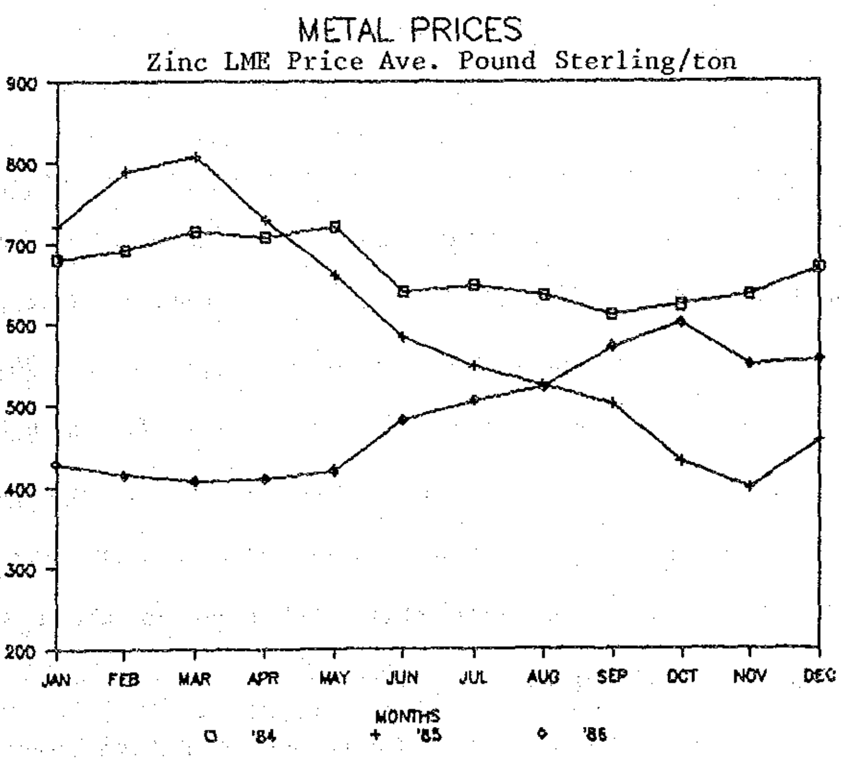




Source: ZCCM.

Fig. 2-5-3 Price Trend of Lead





Source: ZCCM.

Fig. 2-5-4 Price Trend of Zinc

granted for the 1981/1982 fiscal year amounted to as much as K5.0 million, and the cash flow in the last five years shows that the mine has been operated in the red. In this sense, it can be said that the mine's financial standing showed a slight recovery in the 1986/1987 fiscal year.

The Kabwe Mine is thus making intensive operating efforts despite the declining reserves of ores. Since it has noteworthy infrastructure including, in particular, the power generation facilities that ensures a stabilized supply of low-cost power, it is hoped that a new ore deposit will be discovered in its vicinity for full utilization of its existing facilities and human resources. If a new ore deposit is actually discovered and its operation gets started, continued efforts should be made to improve its financial standing by making the most effective use of existing facilities. The abolition of the mineral export tax enforced on December 31, 1987 will serve as an impetus to the improvement of the mine's financial standing.

2.5.2 Impacts on Regional Economy

Copper export from Zambia has consistently accounted for about 90% of the country's total exports over many years in the past (Ref. Table 2-5-1). According to the 1986/1987 data, 74.4% of total lead production of 7,800 tonnes at the Kabwe Mine was supplied to overseas markets, and 94.6% of total zinc production of 22,200 tonnes was also appropriated for export. Lead and zinc from the mine are thus an important source of foreign currency earnings that Zambia has besides copper. Hence, great expectations are entertained for discovery of a new ore deposit that will open up the possibility of continued operation of the mine.

Zambia is divided into nine provinces, and Copperbelt has the largest share of population in the country. The 1980 census shows that the area contains a population of 1.25 million, or 22% of the country's total population. The next most densely populated area is the Lusaka Province where the capital is located, followed by the Central, Eastern and Northern Provinces, each accounting for about 12% of the total population. The population growth rate in the 1969 - 1980 period was by far the highest in the Lusaka Province (6.3%), then came the Copperbelt area (3.9%), Central Province embracing Kabwe as provincial capital (3.3%) and Southern Province (3.0%). All these areas are situated along the railway route running through the central part of the country, which indicates that there is a growing trend of population influx into the central part. Hence, Kabwe holds an important position as the provincial capital of the Central Province where the population is increasing at a relatively high pace.

Table 2-5-1 Copper Export from Zambia

(unit: million K,%)

Year	Total exports	Copper export	Share of copper in total exports
1965	380	343	90
1970	715	681	95
1975	521	472	91
1980	1,023	872	85
1981	937	836	89
1982	951	855	90
1983	1,048	930	89
1984	1,181	1,031	87

Source: Central Statistical Office, Monthly Digest of Statistics, each year.

Analysis of socio-economic conditions of Kabwe City is made difficult by the extreme lack of relevant data. According to the Central Statistics Office, however, the city had a population of 136,000 in 1980, and its estimated population in 1985 was 172,000.

Table 2-5-2 shows a list of main workforce absorbing enterprises located in Kabwe City and estimated numbers of their employees. While the role of railways in accelerating the population inflow into the central part of the country has already been discussed above, the Zambia Railway's head quarter is located in Kabwe City. Besides performing its head office functions, it operates a training center and workshop and has an estimated total of about 4,000 employees, thus ranking as the top workforce absorbing enterprise in the city.

The Kabwe Mine places second after ZR with about 1,800 employees as of November 1987. Since all these mine workers purchase their daily necessities in Kabwe City, it can readily be surmised that the mine plays an important role in providing employment opportunities and maintaining the distribution of consumer goods in the city.

As in any other large cities in the world, Kabwe City has squatter districts such as Kawama, Nakoli, Shamabanse, Kaputula, Natuseko, Chimangemange, Makululu, Katondo and Wanga, and the squatter population as estimated by the Kabwe Urban District Council is about 54,000. Since the greater part of this squatter population comprises the jobless and informal sector workers, one of major economic issues now facing the city is to secure the operation of existing workforce absorbing enterprises and invite new enterprises to set up their plants in the city. In this sense, the Kabwe Mine's continued operation bears closely on the socio-economic development of the city.

Table 2-5-2 Major Enterprises Located in Kabwe City and Estimated Number of their Employees

(1)	Zambia Railways	4,000 persons
(2)	Kabwe Mine	1,800 persons (as of November 1987)
(3)	Mulungushi Textiles	1,600 persons
(4)	Kabwe Urban District Council	1,500 persons
(5)	Amaka Holding	500 persons
(6)	Kabwe Industrial Fabrics	450 persons
(7)	Zambia National Wholesale and Marketing Company	250 persons
(8)	National Milling	200 persons
(9)	Pharmaceuticals	100 persons
(10)	B.R.R. Industries	100 persons
(11)	Kabwe Milling	100 persons

Note: All figures based on the estimate of the Labor Department, Kabwe.