COPPER – ITS GEOLOGY AND ECONOMIC IMPACT ON DEVELOPMENT IN NAMIBIA, ZAMBIA AND THE DEMOCRATIC REPUBLIC OF THE CONGO

A THESIS SUBMITTED IN FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN GEOLOGY

OF

THE UNIVERSITY OF NAMIBIA

BY

DR. SAM NUJOMA

March 2009

Main Supervisor:

Dr. A.F. Kamona (UNAM)

Co-Supervisors:

Dr. B. Mapani (UNAM);

Dr. G. Schneider (Geological Survey of Namibia)

An exceptional specimen of azurite [$Cu_3(CO_3)_2(OH)_2$] from Tsumeb, 6 x 8 cm

ABSTRACT

Copper is the oldest industrial metal known to man and has contributed to the development of many civilizations in the world, including pre-colonial African communities in southern and central Africa, where copper metal was produced and traded on a wide scale centuries before the arrival of Europeans. Despite having produced 10.6 % of world copper metal valued at 193 billion US dollars in the past 100 years, Namibia, Zambia and the Democratic Republic of Congo have functioned mainly as exporters of copper metal rather than as manufacturers of finished copper products. As a consequence, copper mining has not made a significant impact to the economic development of these countries despite the fact that copper has many varied industrial uses. Industrial plants that add value to the copper metal are required in order to enable Namibia, Zambia and the Democratic Republic of Congo to manufacture secondary and tertiary copper products, including cable wire for power transmission and generation, construction and telecommunication as well as electrical and electronic equipment.

TABLE OF CONTENTS

Abstract	iv
Acknowledgements	viii
Dedication	x
Declarations	xi
Chapter 1: Introduction	1
1.1 Copper – The Oldest Industrial Metal	1
1.2 Copper Mining in Southern and Central Africa	2
1.3 Statement of the Problem	4
1.4 Working Hypothesis	6
1.5 Methods and Materials	7
Chapter 2: Geology of Copper	9
2.1 Introduction	9
2.2 Porphyry Copper Deposits	9
2.3 Sediment-hosted Stratiform Copper Deposits	11
2.4 Volcanogenic Massive Sulphide Deposits	14
2.5 Carbonate-hosted Copper Deposits	16
Chapter 3: Pre-Colonial Ancient Mining Sites in Namibia, Zambia and the Democratic Republic of Congo	18
3.1 Introduction	18
3.2 Namibia	22
3.3 Zambia	26
3.4 Democratic Republic of Congo (DRC)	28
3.5 Summary	29
Chapter 4: Modern Copper Production	31
4.1 Introduction	31

4.2 Copper Mining in Namibia, Zambia and the Democratic Republic of Congo 32
4.3 Copper Production in Namibia 33
4.4 Copper Production in Zambia 38
4.5 Copper Production in the DRC 41
Chapter 5: Impact of Copper Production to Local Economies and the Environment in Namibia, Zambia and the Democratic Republic of Congo 46
5.1 Introduction 46
5.1.1 Economic overview of Namibia, Zambia and the DRC 47
5.2 The Colonial Era in Namibia, Zambia and the DRC 52
5.2.1 South-West Africa 55
5.2.2 Northern Rhodesia 59
5.2.3 The Congo Free Sate and Belgian Congo 60
5.3 Developments After Independence 61
5.3.1 Namibia: benefits from large scale mining 61
5.3.2 Zambia: Benefits from large scale mining 65
5.3.3 Democratic Republic of Congo: benefits from large scale mining 74
5.4 Environmental Considerations 81
Chapter 6: Discussion 83
6.1 Pre-colonial Mining in Southern and Central Africa 83
6.2 Copper Production in Namibia, Zambia and the DRC 85
6.2.1 Namibia 85
6.2.2 Zambia 88
6.2.3 The DRC 91
6.3 Potential Economic Benefits From Copper Production in Namibia, Zambia and the DRC 93
6.4 Life After Mining 97

Chapter 7: Recommendations and Conclusions 99

7.1 Recommendations 99

7.1.1 Copper manufacturing 99

7.1.2 Closed copper mines 100

7.1.3 Small scale mining 100

7.1.4 Waste dumps 101

7.1.5 Archaeometallurgy 101

7.2 Conclusions 102

References 104

ACKNOWLEDGEMENTS

One's road to success in academic endeavour is undoubtedly shaped, enhanced and sustained by various kinds of interactions with academicians, industrialists, and indeed individuals from all walks of life. Consequently there are certain individuals and companies whose influence on the writing of this thesis must be acknowledged.

First and foremost I owe a debt of gratitude to Dr. A.F. Kamona and Dr. B. Mapani, who, as my lecturers and supervisors have enriched the research work with a wide and varied experience of much geological knowledge. During my years of research on copper at the University of Namibia (UNAM), I had the good fortune to be under their supervision, both during lecture sessions and field work in Namibia, Zambia and the Democratic Republic of Congo (DRC), respectively. I have learned to appreciate their in-depth knowledge and analysis of geology as a science and its application to economic transformation. I am also grateful for the assistance and encouragement given by other geologists from the Department of Geology at UNAM and the Ministry of Mines of and Energy, particularly Dr. G. Schneider (Director, Geological Survey of Namibia) who provided various kinds of research materials and supervision during my research work.

My gratitude is also due to SAMICOR-SAKAWE Mining Corporation for offering me a bursary during my studies at UNAM. In this regard, Mr. Elieser Nefussy and Mr. Kombadeyedu Kapwanga from SAMICOR are worth mentioning here. I also owe thanks and appreciation to Mrs. Inge Zaamwami-Kamwi (Managing Director of NAMDEB) and Mr. Otto Shikongo (Managing Director of De Beers Marine Namibia), and their respective management teams who introduced me to the Diamond Area No. 1 in the Sperrgebiet and the recovery of diamonds offshore Namibia.

My deep and sincere thanks go to the Governments of Zambia and the DRC for their particular support and warm welcome during my field visits to their respective countries. Thus, special mention goes to Dr. Jacob Mwanza (Chancellor, UNZA), Prof. S. Simukanga (Vice Chancellor, UNZA), Dr. W. Mwenya (then Act. Vice Chancellor, UNZA), Dr. S. Kambani (Dean of School of Mines, UNZA), Prof. Imasiku Nyambe (Geology Department, UNZA), Mr. R.V. Kulkami (General Manager, Konkola Copper Mines), Mr. C.M.C Kabaghe (Manager Corporate Affairs, Mopani Copper Mines), Mr. J.Z. Banda (Mine Manager, Mopani Copper Mines), Mr. Ali D. Simwinga (Town Clerk, Kitwe), Dr. S.C. Mulenga (Manager, Albidon Zambia Limited), Prof. Lufunda Kaumba (Vice Chancellor, University of Lubumbashi), Mr. E. M. Mbaaz (Executive Director, Gecamine), Mr. Kaputo Kalubi (Director, Gécamines), Mr. G. Forrest (Malta Forrest), Dr. J. Cailteux (Manager R&D, Malta Forrest), Mr. W. Sweeta (Zambezi Resources), as well as the management teams of the mining and metallurgical operations in Kolwezi, Kamoto and Likasi, and of course Weatherly-Ongopolo in Kombat and Tsumeb.

I would also like to thank my office staff members, especially Comrade John Nauta, for their constant assistance during my research work. Last but not least, I would like to acknowledge the contribution of my fellow students in the Department of Geology at UNAM with whom I shared memorable field trips.

DEDICATION

I dedicate this thesis to the gallant sons and daughters who sacrificed their precious lives for the genuine Freedom and Independence of Namibia and thus enable future generations to contribute to the economic independence of Africa.

DECLARATIONS

I, Sam Nujoma, declare hereby that this study is a true reflection of my own research, and that this work, or part thereof has not been submitted for a degree in any other institution of higher education.

I, Sam Nujoma, grant The University of Namibia the right to reproduce this thesis in whole or in part, in any manner or format, which The University of Namibia may deem fit, for any person or institution requiring it for study and research; providing that The University of Namibia shall waive this right if the whole thesis has been or is being published in a manner satisfactory to the University.

....	7th April 2009
Dr Sam Nujoma	Date

CHAPTER 1: INTRODUCTION

1.1 Copper – The Oldest Industrial Metal

Copper has the atomic number 29 and it is found between Ni (atomic number 28) and zinc (atomic number 30) on the periodic table. It has a melting point of 1083° C and a boiling point of 2567° C. Copper is usually found in nature in association with sulphur with which it forms sulphide minerals, the most important being chalcopyrite (CuFeS2), bornite (Cu5Fe4S2) and chalcocite (CuS2). Pure copper metal is generally produced from a multistage process, beginning with the mining and concentrating of low-grade ores containing copper sulphide minerals, and followed by smelting and electrolytic refining to produce a pure copper cathode. However, an increasing share of copper is produced from acid leaching of oxidized ores containing malachite, azurite and chrysocolla.

Copper is the oldest industrial metal known to man (Strauss, 1986; Copper Development Association, 2009a), but it is not known exactly when copper was first discovered although earliest estimates place this event around 9,000 BC in the Middle East (Stanczak, 2005). It was probably first used by the Sumerians and Chaldeans of Mesopotamia, after they had established their thriving cities of Sumer and Accad, Ur, al'Ubaid and others, somewhere between 5,000 and 6,000 years ago (Copper Development Association, 2009a). These early people developed considerable skill in fabricating copper and from their centres craftsmanship spread to the river-dwelling people of Egypt, where it continued to flourish for thousands of years long after their own civilization had degenerated (Copper Development Association, 2009a).

Copper has been one of the important materials in the development of human civilization. The discovery of the melting process required to obtain copper metal from its ores was a very important event in human history, as it gave birth to metallurgy and laid the grounds for the development of copper, iron and steel industries. Present-day Israel, Egypt and Jordan were some of the earliest locations of copper smelting sites, dating back to about 4,500 BC (Stanczak, 2005). The Egyptians were one of the first to develop bronze, an alloy of copper and tin, during the Bronze Age (ca. 3,500-1,200 BC) when stone tools were completely replaced by bronze tools (Trifonov & Trifonov, 1985). Archaeological finds on the island of Crete dating back to about 3,500 BC have revealed both copper and bronze articles (Trifonov & Trifonov, 1985). Among the famous mines of the antique are those on the island of Cyprus to which, it has been suggested, copper owes its name (cuprum in Latin) (Trifonov & Trifonov, 1985), although others argue that indeed Cyprus may have gotten her name from copper (Alexander & Street, 1976).

1.2 Copper Mining in Southern and Central Africa

The exact time when copper was first extracted from Southern and Central African deposits by Africans is not known, but it was at least several centuries before the arrival of Europeans as indicated by burial ornamentals made from copper and dated from the 15th century (Stanczak, 2005) and by radiocarbon dates that copper was smelted as early as the year 1420 in the Khomas region of Namibia (Schneider & Seeger, 1992).

Copper smelting sites on the Copperbelt of Zambia and the DRC are estimated at ca. 2,000 BC (Herbert, 2003). The Lualaba and Kalundu sites in the DRC supplied a lot of finished copper jewellery to the east coast of Africa in the late 18th Century and they may be the most ancient sites in Sub-Saharan Africa (AdeAjayi & Crowder, 1985). Remains of copper and iron smelters in the Nchanga area of Zambia (McKinnon & Smit, 1961) indicate that Iron Age Bantu lived in the area subsequent to the Stone Age inhabitants at about 4,300 BC (Clark, 1959).

Sandelowsky and Pendelton (1969) report blast furnace constructions and blast furnace nozzles dated about 500 years before present (ca. 1450) from the Onganja mining site in Namibia, where slag deposits have been found (Hälbich, 1968). Archaeological evidence of copper smelting in the Matchless area west of Windhoek indicate that copper mining occurred there some 400 years ago (Lau, 1987; Schneider, 1998). In northern Namibia, the Ovambos are known to have been the first to smelt copper ores at Tsumeb and in neighbouring Angola (Gebhard, 1999). The early copper mining activity was apparently most intensive during the 17th Century in Namibia (Kinahan & Vogel, 1982). The ancient miners were most likely attracted to the copper-bearing deposits by the bright green colour characteristic of malachite, a hydrated copper carbonate commonly associated with copper deposits in outcrops (Fig. 1.1).

Figure 1.1: An outcrop of green malachite mineralisation at the Copperberg prospect near Dordabis in Namibia (camera cap for scale). The channel of chip sampling near the centre was made by a prospecting company, West African Gold Exploration, in 2008.

Modern mine development and commercial production of copper did not start until the early 1900s, when European mining companies arrived in Sub-Saharan Africa. However, despite the rich history of copper mining in the area, and the fact that Africa's major copper reserves occur in Zambia, where there is an estimated 19 million tonnes of copper ore (U.S. Geological Survey, 2009), copper-based manufacturing industries are still lacking in Namibia, the DRC and Zambia. This lack of local manufacturing industries based on copper resources is due to the historical role of these countries as suppliers of raw materials to the industrialized nations of the western world. In addition, since the mining companies are still largely foreign owned, the owners have no interest in setting up local manufacturing industries based on copper. Furthermore, even after independence, the governments of these respective countries have not taken any purposeful action to promote the development of local industries, thus perpetuating the colonial role of raw material supplier to the former colonial masters.

It is not yet too late to take advantage of the available copper resources in the area since the importance of copper will most likely continue with the rapid growth of the computer industry on a global scale as well as the Chinese and Indian industries which require massive amounts of copper for industrialization.

1.3 Statement of the Problem

This thesis examines the occurrence of copper in the DRC, Namibia and Zambia and the impact of copper mining on the economies of these countries. Major copper production in the DRC, Namibia and Zambia started at the beginning of the 20th Century, mainly from the world's richest stratabound sediment-hosted deposits in the Zambia-DRC Copperbelt (Mendelsohn, 1961; Fleischer et al., 1976; Boyle et al., 1989; Binda, 1995; Robb et al., 2003; Cailteux et al., 2005a) and the Otavi Mountain Land (OML) of Namibia (Schneider & Seeger, 1992; Kamona, 2003; Kamona & Günzel, 2007).

In addition, volcanic associated copper deposits that occur along the Matchless Belt of Namibia, which incidentally hosts the oldest underground mine in the country, the Matchless Mine (Schneider & Seeger, 1992; Borg, 2000; Killick, 2000) have also been exploited.

These deposits are geologically diverse and have different tonnages and grades of copper. Some of the main deposits (e.g. Tsumeb) have already been mined out, whereas numerous smaller occurrences have not been geologically investigated and evaluated since the colonial times. There is therefore an important need to evaluate the various deposit types and reserves, including other previously unexploited occurrences in order to provide information and data for future development and mining of copper in the region. Research on deposit types and their respective copper reserves can in turn form a basis for large- and small-scale mining as well as the development of copper based manufacturing industries in southern and central Africa.

Namibia, Zambia and the DRC have been principal producers of copper, which is an essential industrial metal because of its high electric and thermal conductivity, resistance to corrosion, high ductility, good malleability and high strength as well as its ease of alloying to form alloys such as bronze (with tin) and brass (with zinc). The largest single consumption of copper (about 50%) is in the electrical engineering industry where it is used in the manufacture of electrical equipment and appliances, including cable wires, electric motors and dynamos (Alexander & Street, 1976). The only downstream processing of copper to manufacture copper rods and electrical conductors for sale in domestic and foreign markets is done by Metal Fabricators of Zambia (ZAMEFA) in Luanshya, Zambia.

The main challenge for Namibia, Zambia and the DRC is therefore to take advantage of the copper they produce to manufacture finished products based on copper or “Ongopolo", as it is known in the Oshivambo language. It is the aim of this thesis to analyse the historic role that copper played for the economies of Namibia, the DRC and Zambia and to make a contribution towards the establishment of manufacturing plants based on "Ongopolo" by providing relevant scientific information on copper resources in Namibia, Zambia and the DRC.

1.4 Working Hypothesis

It is hereby proposed that the production of mineral resources such as copper for local or regional consumption can form the basis of economic independence and development in most African countries, especially those endowed with vast mineral resources, Namibia included. It is therefore the objective of this thesis to investigate the geological nature of copper deposits in the region in terms of deposit types and potentially available copper resources still remaining to be exploited, including the numerous small occurrences which have been previously regarded as uneconomic by big mining companies. The geological knowledge and data on copper deposits may provide a basis for evaluating the feasibility of local copper based industries to produce finished products such as copper wires, motors and other electric appliances.

It is the contention of this research study that some of the small copper occurrences may be economically feasible for local exploitation on a small-scale, particularly in times of high copper prices, such as those experienced before the onset of the current global economic crisis, provided that local or regional markets are available for the consumption of the copper metal to manufacture finished products based on copper.

It is further proposed that small- to medium-scale production by indigenous enterprises or cooperatives, coupled with large-scale mining aimed at supplying local industries can and will contribute to the development of downstream industries based on mineral raw materials, as long as local governments and regional bodies like SADC are willing to support such projects. Such a development strategy will result in employment creation and local ownership of resources.

1.5 Methods and Materials

A literature survey on copper mining and production in Southern and Central Africa and its impact on development was conducted in order to review and synthesize available data and information, including sources such as Bowen and Gunatilaka (1977), Hartmann (1986), United Nations Institute for Namibia (1987), Kirkham (1989), Geological Survey of Namibia (1992), Evans (1993), Schneider (2004), and Kamona and Günzel (2007).

The socio-economic impacts of mining and exploration during the German colonial period have been researched by Drechsler (1996), while the role of mining in the economy of Namibia between 1950 and 1985 is outlined in Hartmann (1986). The United Nations Institute of Namibia (1987) has considered the legal framework and mineral development strategies for the mining industry. On a more regional scale, investment opportunities in industrial minerals in southern Africa have been discussed at various SADC and other international forums (e.g. Mambwe et al., 1995).

During this study, copper production data has been obtained and compiled from the mineral databases of the U.S. Geological Survey and supplemented by government sources and mining companies in the DRC, Namibia and Zambia, as well as Belgium. The quantitative data have been evaluated with the aid of the standard Microsoft software programme EXCEL in order to determine the amount of copper metal produced and the wealth generated from these regions. In addition, the status of copper mining at present has been examined in detail through mine visits to major copper producing areas, including the Kombat Mine and the Tsumeb Smelter in Namibia, the Central African Copperbelt of the DRC (Lubumbashi, Luiswishi, Kolwezi) and Zambia (Nkana Mine), as well as smelting mining sites in the Rehoboth area of Namibia.

The geological information and data obtained during the study has been used to recommend possible ways and means of copper exploitation, including small-scale mining of previously neglected deposits, with the objective of encouraging the development of manufacturing plants that will add value to the copper metal by producing copper products such as cable wires, ingots and electrical appliances (e.g. computers, motors).

In order for the copper mining to be sustainable, it is envisaged that best practices will have to be adhered to safeguard the environment. Relevant best practices which take into account the local community and the environment are recommended in accordance with suitable codes of conduct such as those of Albidon (2007) and the "seven questions" developed by the International Institute for Sustainable Development (IISD) of Canada to assess the sustainability of mining projects (IISD, 2002).

The study has also included the various technological uses of copper in order to provide relevant information required for investments in the proposed locally based manufacturing plants that will provide finished products for various industries, including the building, computer, electrical, telecommunication and automotive industries all of which utilize copper in various forms and quantities. Appropriate recommendations have also been made regarding utilization of revenues from copper mining, taking into account the local needs of the community and potential future economic projects, once the copper ore has been mined out in particular mining districts.

CHAPTER 2: GEOLOGY OF COPPER

2.1 Introduction

Geologically, copper occurs mainly in porphyry, sediment-hosted stratiform copper (SHSC), volcanogenic massive Cu-Pb-Zn sulphide, and in hydrothermal vein type deposits. Most of the world´s copper (50-52%) is produced from porphyry copper deposits (Gustafson & Williams, 1981; Guilbert & Park, 1986), which are large tonnage (200 million tonnes of ore on average), low- to medium- grade (most deposits contain 0.6-0.9 % Cu, some have <0.35% Cu and a few have 1-2 % Cu) deposits containing disseminated copper sulphides (mainly chalcopyrite CuFeS2) with variable but minor molybdenite (MoS2) (Guilbert & Park, 1986; Sawkins, 1990). These porphyry deposits are mainly associated with zones of current or former subduction activity, especially along the Mesozoic-Cenozoic western margins of North and South America (Fig. 2.1).

2.2 Porphyry Copper Deposits

A porphyry copper deposit (PCD) is a large, low- to medium-grade deposit, primarily of chalcopyrite and molybdenite, in which hypogene sulphide and silicate zoning occurs due to potassic-propylitic alkali metasomatism and phyllic-argillic hydrolitic alteration, and which is temporally and spatially related to an epizonal calc-alkaline porphyritic intrusion (Guilbert & Park, 1986). They occur along linear, calc-alkaline volcano-plutonic arcs related to subduction processes and they tend to form in compressional arc systems such as those along the western margins of North and South America. Surficial mining from huge open pits is the method usually employed for porphyry

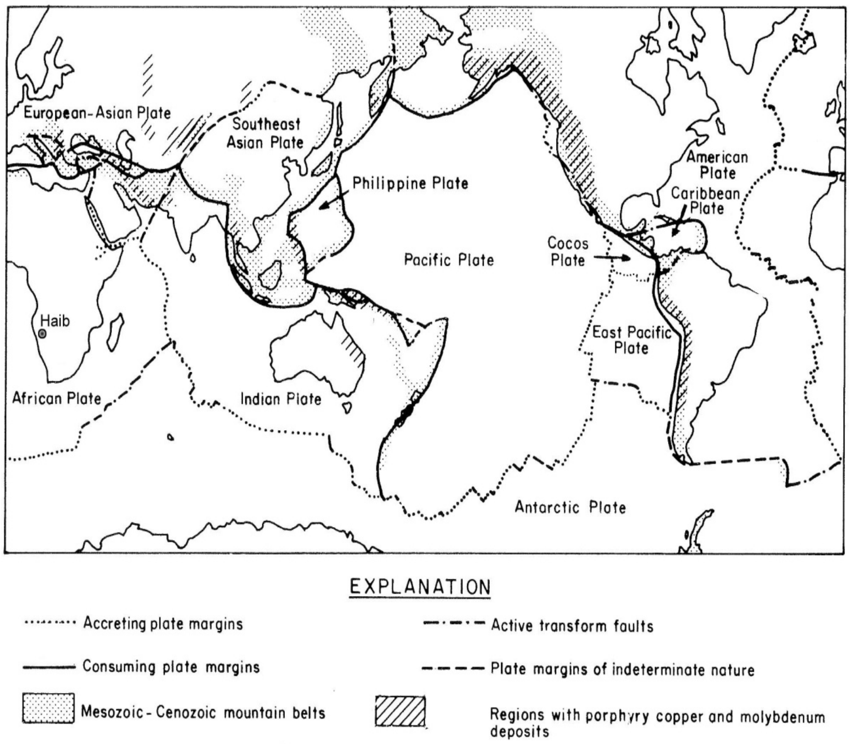


Figure 2.1: Porphyry copper belts of the world (after Sawkins, 1990) with the location of the Haib porphyry deposit in Namibia.

copper deposits because of the large volume of material close to surface. The Chuquicamata porphyry copper deposit in Chile, with 2 billion tonnes of ore at an average grade of 1.2% Cu is an example of one of the largest producers of copper in the world with 650,000 tonnes produced per year (Guilbert & Park, 1986; Codelco, 2007). The 1.8 billion years old Haib porphyry copper deposit in Namibia (Fig. 2.1) is one of the oldest porphyry copper deposits in the world (Guilbert & Park, 1986; Minnitt, 1986). The still inactive Haib deposit is estimated to have 244 million tonnes (Mt) of copper ore at a grade of 0.37% Cu, using a cut-off of 0.3% Cu (Copper Resources Corporation, 2005).

According to Gustafson and Hunt (1975) the essential elements of a genetic model for porphyry Cu deposits are:

1. Shallow emplacement of a complex series of porphyritic dikes or stocks in and above the cupola zone of a calc-alkaline batholith;
2. Separation of magmatic fluids and simultaneous introduction of copper, other metals, sulphur, and alkalies into both porphyries and wall rocks;
3. Establishment and inward collapse of a convective groundwater system which reacts with the cooling mineralized rocks.

The difference and unique features exhibited by individual deposits reflect the imprint of local variables upon the basic model. The local variables include depth of emplacement, availability of groundwater, volume and timing of successive magma advances, the concentration of metals and sulphur and other volatiles in the magmas, as well as the depth of exposure.

2.3 Sediment-hosted Stratiform Copper Deposits

Sediment hosted stratiform copper (SHSC) deposits are next to porphyry deposits in terms of world copper reserves and production (about 27%) (Gustafson & Williams, 1981). These SHSC deposits are economically the most important type of mineral deposits in the Neoproterozoic orogenic belts of Central and Southern Africa (Fig. 2.2), which contain the world famous Cu-Co deposits in the Copperbelt of the DRC and Zambia (Mendelsohn, 1961; François, A., 1974, 1987; Fleischer et al., 1976; Kirkham, 1989; Binda, 1995; Cailteux et al., 2005a). According to the latest estimates (Cailteux et al., 2005a), the Neoproterozoic Central African Copperbelt contains a total of 140 Mt of copper and 60 Mt of cobalt metal.

Fig. 1.- Distribution and age of typical sediment–hosted stratiform copper deposits and districts.
PROTEROZOIC. 1: Zambia–Zaïre Copperbelt; 2: Ghanzi Belt, Botswana; 3: Damara Belt, Namibia; 4: Belt–Purcell Supergroup, Rocky Mountains; 5: White Pine, Michigan; 6: Udokan, Siberia; 7: Adelaidean, Australia.
PALEOZOIC. 8: Permian of New Mexico, Oklahoma and Texas; 9: Negra Huanusha, Peru; 10: Germany–Poland Kupferschiefer; 11: Timma, Israel, and Wadi Araba, Jordan; 12: Dzhezkazgan, Kazakhstan.
MESOZOIC. 13: Triassic of New Mexico; 14: Coloso, Chile.
CENOZOIC. 15: Neogene deposits of the central Andes; 16: Neogene deposits of the Tarim Basin, China.

Figure 2.2: Distribution and age of typical sediment-hosted stratiform copper deposits and districts (Binda, 1995). PROTEROZOIC: 1. Central African Copperbelt; 2. Ghanzi Belt, Botswana; 3. Damara Belt, Namibia; 4. Belt-Purcell Supergroup, Rocky Mountains; 5. White Pine, Michigan; 6. Udokan, Siberia; 7. Adelaidean, Australia. PALAEOZOIC: 8. Permian of New Mexico, Oklahoma and Texas; 9. Negra Huanusha, Peru; 10. Kupferschiefer of Germany and Poland; 11. Timma, Israel and Wadi Araba, Jordan; 12. Dzhezkagan, Kazakhstan; MESOZOIC: 13. Triassic, New Mexico; 14. Coloso, Chile. CENOZOIC: 15. Neogene deposits, Central Andes; 16. Neogene deposits of the Tarim Basin, China.

In central Namibia sediment-hosted Cu-Ag mineralization occurs in clastic sedimentary rocks (Ruxton, 1986; Borg, 1995) in the Mesoproterozoic sedimentary basins of Sinclair, Klein Aub and Dordabis and Witvlei (Fig. 2.3). The most important deposit is the Klein Aub Mine which initially had a total estimated reserve of 7.5 Mt and produced 5.5 Mt tonnes of ore grading 2% Cu and 50 g/t Ag between 1966 and 1987 (Borg, 1995). Although the Cu-Ag mineralization has been previously considered to be comparable to the Central African Copperbelt (Ruxton, 1986), it appears that the copper mineralization at Klein Aub may be epigenetic rather than syndiagenetic as it is structurally controlled by faulting (Borg, 1995).

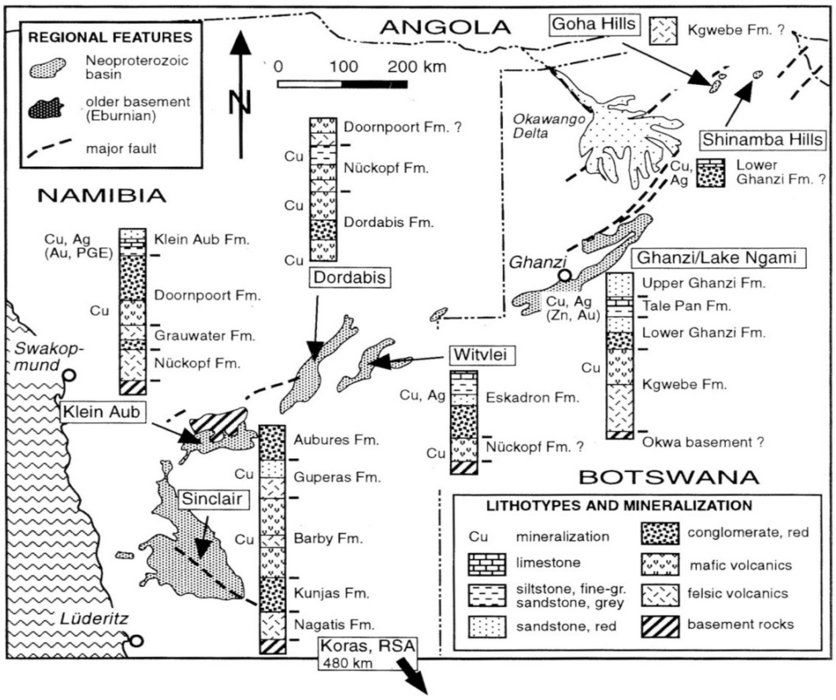


Figure 1: Regional distribution, stratigraphic subdivision and principal lithotypes of the Neoproterozoic basins in Namibia and Botswana and stratigraphic position and metal association of known copper deposits.

Figure 2.3: Location of Mesoproterozoic sedimentary basins in Namibia and Botswana with locations of known copper mineralization, including the Klein Aub deposit (from Borg, 1995).

The unifying feature for all sediment-hosted, stratiform base metal deposits is that they were all developed in a structural setting that permitted heated, basinal brines to be moved to a shallow site of sulphide deposition (Binda, 1995). Many different theories have been proposed for the origin of the Copperbelt ores since the late 1920s, including (Sweeney et al., 1991; Sweeney & Binda, 1994): hydrothermal epigenetic, syndiagenetic, syngenetic, diagenetic, and hydrothermal-diagenetic. Similarly, several possible sources of the metals contained in the Copperbelt orebodies have been proposed, including granite-derived magmatic fluids, hidden-magma-derived hydrothermal fluids, leaching of basaltic rocks at depth, leaching of the sedimentary pile, and erosion of the pre-Katangan basement (Sweeney et al., 1991; Sweeney & Binda, 1994, Binda, 1995). However, the most likely source of both copper and cobalt are the rocks of the Basement Complex, whereby the metals were transported both in surface- and ground waters, and the main mineralizing event took place during early diagenesis with sulphide precipitation occurring via bacterial reduction of seawater sulphate.

The erosion of the pre-Katangan basement could have led to the concentration of the metals, since the basement contains anomalous amounts of copper as well as cobalt. Copper concentrations occur in granitic rocks and in the rocks of the Lufubu Group and Muva Supergroup. More significantly, porphyry-type deposits have been recognised within the basement, for example at Samba, which contains 50 Mt grading 0.7% Cu (Wakefield, 1978). Corroborating evidence for a basement source of the metals is indicated by the lead isotopic composition of Lower Roan copper and cobalt sulphides, which suggest an upper crustal origin (Carr et al., 1986; Richards et al., 1988; Kamona et al., 1999).

2.4 Volcanogenic Massive Sulphide Deposits

Volcanogenic massive sulphide (VMS) deposits are major sources of Zn, Cu, Pb, and Ag and they are third in importance, containing about 10% of the world's mineable copper (Gustafson & Williams, 1981). They include the Kuroko and Besshi type deposits of Japan hosted in felsic volcanic and mixed sedimentary-volcanic environments respectively, the Cyprus type deposits associated with ophiolitic suites and tholeiitic volcanism and the primitive Achaean deposits hosted in basaltic to rhyolitic suites and clastics mainly in greenstone belts (Hutchinson, 1980; Franklin et al., 1981; Scott, 1989).

The 350 km long Matchless Amphibolite Belt in the Damaran Orogen of Namibia (Fig. 2.4) is associated with 18 Neoproterozoic massive sulphide Cu-Au-(Zn-Ag) deposits, which have been classified as Besshi-type (Adamson & Teichmann, 1986; Breitkopf & Maiden, 1988; Killick, 2000). The amphibolites represent metamorphosed tholeiitic basalts formed in an extensional tectonic setting. Deposits that have been mined in the past included Matchless, Gorob, Hope and Otjihase. The Otjihase and Matchless mines were active until recently, but have been put under care and maintenance due to the current financial crisis. Otjihase is an underground mine consisting of massive and semi-massive sulphides hosted in magnetite quartzite and quartz-chlorite-biotite schist of the Kuiseb Formation with narrow amphibolite horizons of the Matchless Member. Ore reserves are estimated at 16 Mt with 2.2 % Cu, 1.2 g/t Au and 12 g/t Ag (Killick, 2000). The Matchless Mine contains 3 Mt of ore with average grades of 2 % Cu, 14.8% S, 10-20 g/t Ag and 0.5-1.5 g/t Au (Ongopolo, 2005, pers. comm.). It has been mined intermittently, and was last re-opened in 2005.

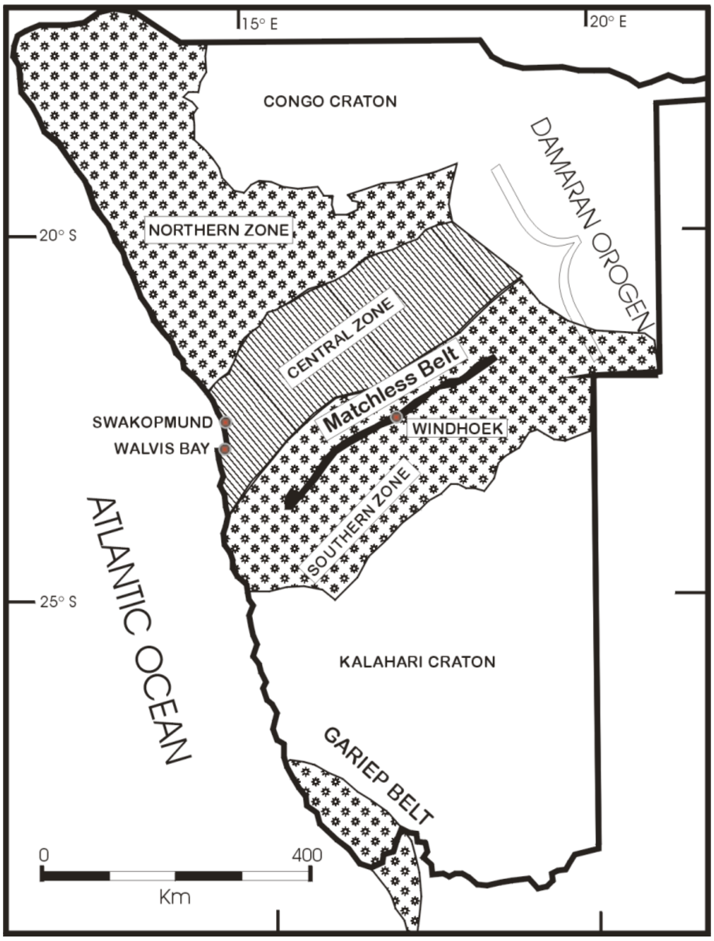


Figure 2.4: Location map of the 350 km long Matchless Amphibolite Belt in the Southern Zone of the Damara Orogen (modified after Killick (2000)).

The ore genesis of VMS deposits is associated with submarine volcanism in various environments and they typically occur as lenses of polymetallic massive sulphides that form at or near the seafloor in submarine volcanic environments (Hutchinson, 1980; Guilbert & Park, 1986; Sawkins, 1990). The most common feature among all types of VMS deposits is that they are formed in extensional tectonic settings, including both oceanic seafloor spreading and arc environments. Most ancient VMS deposits that are still preserved in the geological record formed mainly in oceanic and continental nascent-arc, rifted arc, and back-arc settings. Primitive bimodal mafic volcanic-dominated oceanic rifted arc and bimodal felsic-dominated siliciclastic continental back-arc terranes contain some of the world's most economically important VMS districts (Galley et al., 2007).

2.5 Carbonate-hosted Copper Deposits

Carbonate-hosted base metal deposit in the DRC, Namibia and Zambia have recently been reviewed by Kamona and Günzel (2007) and Kampunzu et al. (in press). These stratabound epigenetic Zn-Pb-Cu deposits also contain variable amounts of minor Cd, Co, Ge, Ag, Re, As, Mo, Ga, and V. Economic orebodies occur mainly as irregular pipe-like bodies associated with collapse breccias and faults as well as lenticular bodies sub-parallel to bedding. They include the Tsumeb and Kombat deposits in the Damara Orogen of the OML (Lombaard et al., 1986; Innes & Chaplin, 1986) and the Kipushi deposit in the DRC (De Vos et al., 1974; De Magnée & François, 1988).
From1906 to 1996, the now closed Tsumeb Mine was a major producer of Cu, Pb and Zn, as well as by-product As, Sb, Ag and Ge. A total tonnage of 30 Mt with average grades of 10.45% Pb, 4.42% Cu, 3.49% Zn, and 125g/t Ag was mined. The recently closed Kombat Mine had total reserves of 18.5 Mt with relatively lower grades of 2.14% Pb, 2.79% Cu, 1.5% Zn and 25 g/t Ag (Kamona & Günzel, 2007).

The polymetallic Kipushi deposit in the DRC has produced significant quantities of copper (4.08 Mt) and zinc (6.6 Mt) as well as other metals (Pb, Cd, Ge and Ag) over its long history of mining from 1922 to 1993, when operations were suspended (De Magnée and François, 1988; Kampunzu et al., in press). The remaining ore resources down to the 1,500 m level are estimated at more than 5 Mt of Zn, 500,000 t of Cu, and 100,000 t Pb contained metal from ores averaging 21.4% Zn, 2.1% Cu and 0.88% Pb (Kampunzu et al., in press). Other rare metals from this unique deposit include Cd, Co, Ge, Ag and Re with lesser amounts of As, Ga, Mo, Bi, Hg, Ni, Sb, Se, Sn, Te and V (De Vos et al., 1974; Intiomale & Oosterbosch, 1974; Cailteux, 1988).

Hydrothermal carbonate-hosted base-metal sulphide deposits such as Tsumeb, Kombat and Kipushi represent epigenetic replacement deposits in the Pan-African Damaran-Lufilian Orogen. They range in age from Neoproterozoic to Early Palaeozoic (Kamona et al., 1999; Schneider et al., 2007). Stable and radiogenic isotope and fluid inclusion data (Hughes et al. 1984; Kamona et al., 1999; Chetty & Frimmel, 2000) indicate that these hydrothermal carbonate-hosted deposits form from highly saline, high temperature fluids derived from formation waters that had equilibrated with sedimentary rocks within a continental rift environment (Kamona & Friedrich, 2007).
The lead isotope data for Tsumeb and Kipushi indicates derivation of metals from upper continental crustal rocks (Kamona et al., 1999; Schneider et al., 2007). Possible source rocks of the ore include basement rocks and disaggregated rocks of the basement that make up the sedimentary pile in the Owambo and Katanga Basins, respectively, including shale, sandstone and mafic igneous rocks (Hughes et al. 1984; Kamona & Friedrich, 1994; Chetty & Frimmel, 2000).

CHAPTER 3: PRE-COLONIAL ANCIENT MINING SITES IN NAMIBIA, ZAMBIA AND THE DEMOCRATIC REPUBLIC OF CONGO

3.1 Introduction

The earliest mining activity in Sub-Saharan Africa has been dated at 42,000 BC (Cook, 1963) and occurred at the Pomungwe cave in the Matopos area in Zimbabwe, which is part of the ancient mining site of Gokomere-Ziwa (Fig. 3.1). Younger ages have been reported from other sites, including Chowa near Kabwe (28,000 B.C., Dart & Beaumont, 1969), the Kapwirimbwe site in Zambia, and the Ngwenya Iron Ore Mine, Swaziland (7,690 ± 80 B.C., Boshier, 1965), in the South African Coastal Belt (Fig. 3.1). This early mining may have initially been mainly for iron and manganese oxides, such as ochre, pyrolusite and hematite used in cosmetics (Beaumont, 1973; Miller, 1995). The mining for metals, including iron, copper, gold and tin in southern Africa is at least 2,000 years old, but only the past 200 years of this pre-historic indigenous activity are well documented (Miller, 1995). The earliest date for an indigenous copper mine is about 770 AD (Van der Merwe & Scully, 1971) from the extensive copper occurrences at Phalaborwa, the main copper producer in South Africa for many years.

Numerous indigenous ancient mining and metallurgical sites, which were active for many centuries prior to the arrival of the early European prospectors and explorers, have been found in southern and central Africa (Gunning, 1961; Dart & Beaumont, 1969; Sandelowsky, 1974; AdeAjayi & Crowder, 1985; Miller, 1995; Herbert, 2003; Henry & Wilson, 2006) (Fig. 3.1). Indigenous mining and metals technology in these African centres is estimated to have been active from about 300 B.C. to 1100 A.D. and was spread largely through Bantu migrations across the continent (AdeAjayi & Crowder, 1985).

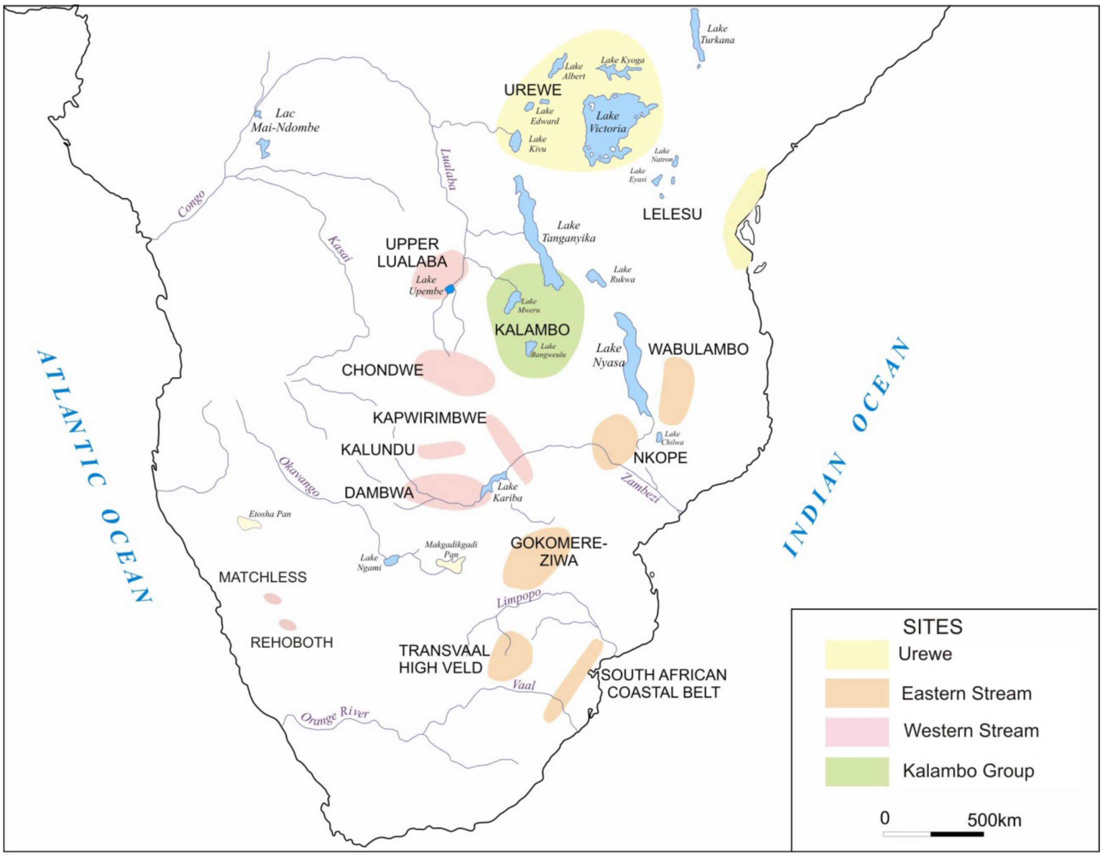


Figure 3.1: Location of the main metal working sites in Southern Africa (modified after AdeAjayi & Crowder, 1985) with the location of the Rehoboth and Matchless sites in Namibia.

In south-west Asia and southern Europe, especially Spain, a “Copper Age” succeeded and replaced the use of stone as a material for tools and weapons (AdeAjayi & Crowder, 1985). The copper and bronze technology, which had already been actively used in Egypt, the Middle East and Persia, spread down to the Great Lakes of Africa where it reached the shores of Lake Victoria around 300 B.C. Archaeological artefacts and records found in several museums in southern Africa (e.g. Livingstone, Choma, Rehoboth and Windhoek) show how rapidly this metal technology spread.

Iron and copper exploitation in the first millennium AD expanded rapidly around the beginning of the second millennium AD, when large trading towns, including Great Zimbabwe, were established through the Indian Ocean trade that flourished from about 800 AD (Huffman, 1974; Miller & Van der Merwe, 1994; Miller, 1995). Copper was a medium of exchange, a medium of art and a medium of culture among the different peoples in sub-Saharan Africa (Fig. 3.2) and the early copper mining activity was apparently most intensive during the 17th Century (Gunning, 1961; Kinahan & Vogel, 1982).

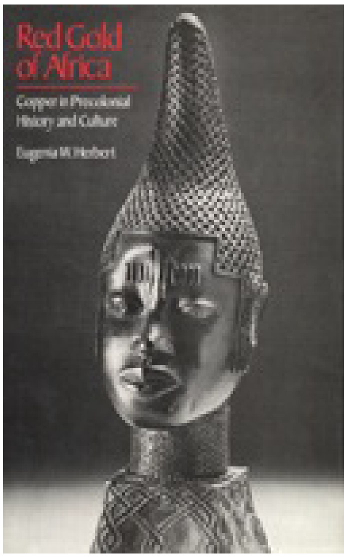


Figure 3.2: A well illustrated cover of the book by Herbert (2003) where copper is known as the “Red Gold of Africa” used in culture, jewellery and religious ceremonies.

Intra- and international trade in copper ore and finished products such as implements (arrows, spears, axes), jewellery (bangles, beads, rings) and copper ingots became established on both the western and eastern coastal regions of Sub-Saharan Africa as indicated by the modern interdisciplinary study of archaeo-metallurgy (Sandelowsky & Pendelton, 1969; Miller, 1980; AdeAjayi & Crowder, 1985; Miller, 1995; Henry & Wilson, 2006).

The main metal working sites can be distinguished as the Urewe Sites centred around Lake Victoria in East Africa, which includes the coastal Lelesu site in Tanzania; the Kalambo Site, located in the area of Lake Tanganyika, Lake Mweru and Lake Bangweulu, which includes the Bangweulu sites in modern day Zambia; the Eastern Stream Sites consisting of Mwambulambo on the western side of Lake Malawi, Nkope in the Shire and Zambezi valley confluence area and Gokomere-Ziwa in present day Mozambique and Zimbabwe, the Transvaal Highveld in South Africa´s regions of Gauteng and Mpumalanga and the South African coastal belt in the area of Kwazulu Natal (AdeAjayi & Crowder, 1985).

The Urewe sites were active from about 300 BC, at the height of Bantu migrations from West Africa, whereas the Eastern Stream sites of Nkope, Gokomere-Ziwa and Mwabulambo were active later on, although there is no direct evidence for this except for the fact that settlement around these areas can be proved from about 200 B.C. (AdeAjayi & Crowder, 1985). The Western Stream sites of Upper Lualaba, together with the Chondwe and Kapwirimbwe sites were some of the most active. Although the Kalundu site is at least 4,000 years old, it is not yet well established when metal technology exactly begun and ended in the area. The Dambwa sites in Zambia are believed to have served the western part of Africa in Angola and neighbouring Namibia.

A comprehensive study on pre-colonial copper mining in Africa was undertaken by Herbert (2003) (Fig. 3.2), to which the reader is referred for more details. Herbert (2003) lists all the important metal-technology centres in Africa, and suggests that not all the people possessed this technology. Only a few of them used it to enhance trade and the rise of their kingdoms. According to Miller (1995), the wealth generated by intensive mining, metallurgical practice and metals trade is probably the single most significant factor in formative urbanization, social stratification and state formation.

The early copper mining activity was apparently most intensive during the 17th Century in Namibia (Kinahan & Vogel, 1982), and 18th Century reports of Portuguese explorers record the production of copper and iron in the Katanga (Gunning, 1961).

3.2 Namibia

Early mining activities by indigenous people have been traced in the areas around Tsumeb, Matchless, Onganja, Oamites and Rehoboth (Kinahan & Vogel, 1982; Henry & Wilson, 2006). Evidence from pieces of copper slag indicate that Tsumeb was an active centre of copper mining, which was mainly undertaken by the Ovambo people, however, it is also reported that San people smelted copper ore and traded it with the Ovambo people. The Ovambo people also travelled from their traditional homeland in the north to mine the copper oxide ores in Tsumeb and as far south as Onganja in the Okahandja district (Miller, 1980). Slag deposits have also been found at Onganja (Sharpe, 1962; Hälbich, 1968), whereas Sandelowsky and Pendelton (1969) reported blast furnace smelters and nozzles dated at about 500 years B.P. (ca. 1450). The Onganja mining site appears to have been a popular site due to the presence of native copper (Cairncross & Moir, 1996). Sharpe (1962) reports that:

"Several pieces of copper slag from native smelters show that copper was worked in the area long before the coming of the white man"

The better known ancient sites in the Matchless Mine area appear to have been worked at the same time as the Onganja site (Kinahan & Vogel, 1982). Other mining sites in Namibia include Drierivier in Rehoboth (Fig. 3.3), Tzamin near Outjo, the Nosib Mine area and Klein Aub (e.g. Miller et al., 2005). Radiocarbon dates show that copper was smelted as early as 1420 in the Khomas region in Namibia (Schneider & Seeger, 1992), a centre of copper production with radiocarbon dates of smelting sites ranging from the 15th to the 19th centuries (Kinahan & Vogel, 1982). A furnace with associated fragments of stone tuyères and possible Khoi pottery near Rehoboth has been dated at 1650 ± 20 A.D. (Sandelowsky, 1974). Thus, active centres of metal working in ancient times were present in Namibia up to the time when European explorers arrived in the 18th Century and found goods made out of copper in the coastal area of Namibia, but no knowledge of metal working (Miller et al., 2005).

The Europeans were told of copper ores and metal smiths who lived in the central highlands of Namibia and traded the copper metal for livestock (Kinahan, 1980). The ancient workings facilitated the re-discovery of mineral deposits such as the Swartmodder orebody, which is considered to be the most likely source of malachite smelted at the Drierivier site (Miller et al., 2005). The copper used for smelting was sourced from numerous malachite outcrops that were common in central Namibia, like for example the malachite occurrences in the Rehoboth area (Fig. 3.3).

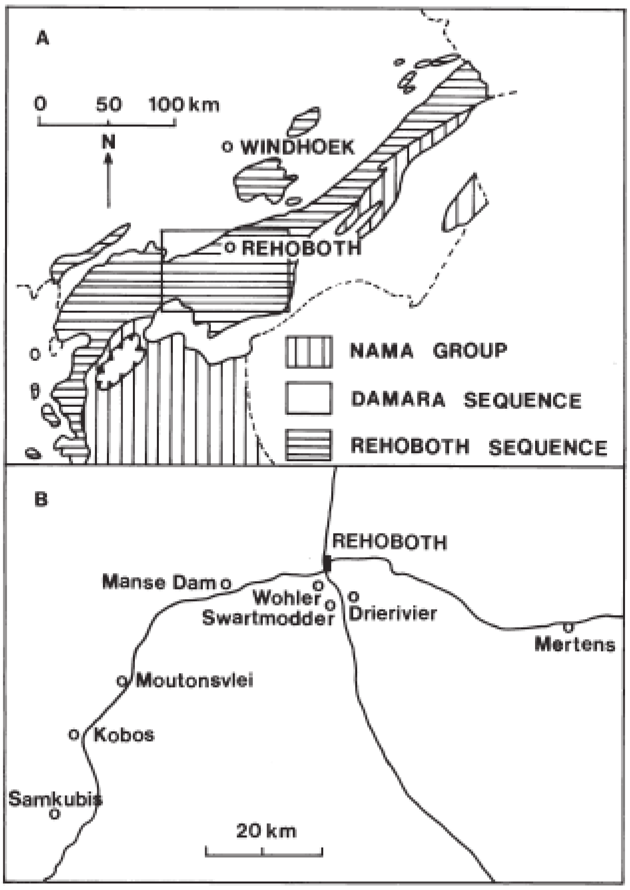


Figure 3.3: A. Location of Rehoboth and Windhoek in relation to the generalized geology of central Namibia. B. Location of the Drierivier copper smelting site south of Rehoboth and malachite outcrops in the Rehoboth area (from Miller et al., 2005).

\Archaeological artefacts stored in the Windhoek Museum suggest that the sites near Tsumeb, Matchless, Oamites, Onganja and Rehoboth were quite advanced and had skilled blacksmiths who smelted the copper ore and worked the copper metal (Figs. 3.4, 3.5, 3.6). Copper beads found in central Namibia were manufactured using simple forced draught furnace technology (Miller & Kinahan, 1992) and the beads were apparently exchanged for livestock (Kinahan, 1980, 1991). The unique stone based smelting technology (Fig. 3.6c) used in central Namibia contrasts with the usual ceramic technology for furnaces and tuyères (blast furnace nozzles) used by other Iron Age cultures (Miller & Sandelowsky, 1999).

Figure 3.4: Bellows used to smelt copper in the Onganja, Oamites and Rehoboth areas (Rehoboth Museum, Namibia).

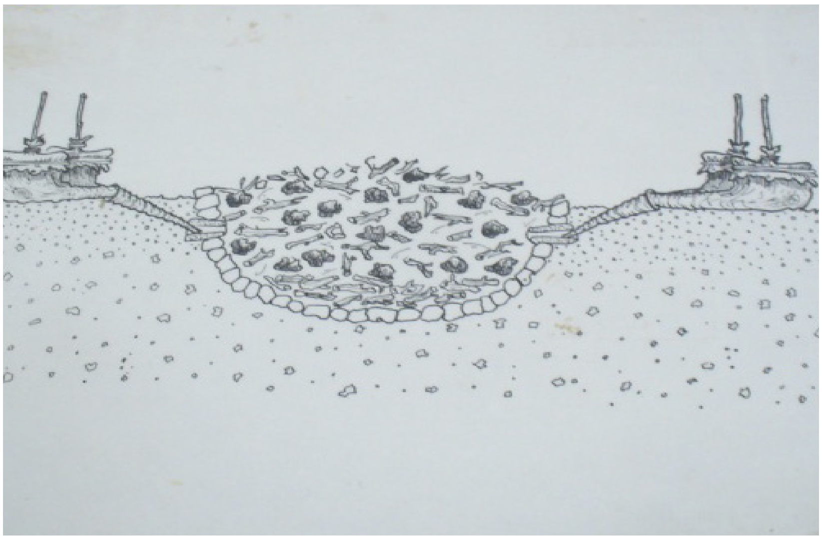
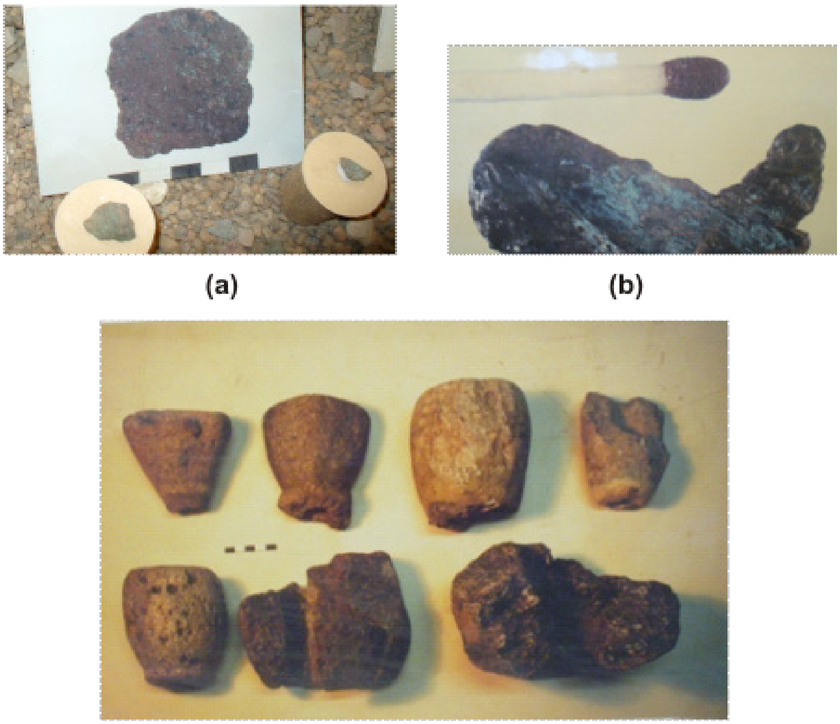


Figure 3.5: Configuration of bellows in the smelting of copper ore, as reconstructed from the archaeological sites at Drierivier near Rehoboth.



(a) (b)

(c)

Figure 3.6: Specimens and artefacts at the Rehoboth Museum. (a) Green malachite ore used to produce copper using coal as a source of energy. (b) Finished copper metal (matchstick for scale). (c) Carved stones used to channel air into the furnace at the Drierivier site (the bottom right pipe is about 8 cm long).

Although the Khoi-Khoi were active at the Oanob river site in Rehoboth, it is not well known whether the San people in Namibia worked copper before the arrival of the Bantu speakers such as the Ovambo and Herero speaking groups. The smelting sites were probably a result of cultural diffusion from the surrounding Iron Age cultures (Miller et al., 2005) of the Bantu speaking people. However, the stone-based smelting technology used in central Namibia suggests local innovation (Miller & Sandelowsky, 1999) and the Khoi-Khoi probably represent the most ancient group in Africa utilizing metallurgical technology.

The trade in metals was mainly between the Ovambo and the San speaking peoples. Before the arrival of the Ovambo speakers, the San people had some agreements with the Damara speakers concerning metallurgical technology, however the San for some reason, did not want to pursue relations with the Damara people (Sharpe, 1962). In contrast, the Ovambo speakers mined and roasted copper with the help of the San people at Tsumeb, Onganja and Matchless (Sharpe, 1962; Hälbich, 1968; Miller, 1980) which were the main centres of activity for a long time (Caincross & Moir, 1996).
The early European explorers of South West Africa (Namibia) are said to have been surprised by the enterprise that happened at Onganja and Tsumeb, the record being borne by the slag that was left behind (Caincross & Moir, 1996). It is not well known why the Herero speaking people were not interested in this lucrative trade which was dominated by the Ovambos at this time. The latter travelled to Lobito Bay in Angola (Portuguese West Africa), where they exchanged the copper ore for other wares, such as clothing traded with the Portuguese (Sharpe, 1962).

3.3 Zambia

Dart and Beaumont (1969) show evidence of the earliest mining sites in Zambia to be from about 28,000 years ago, when iron ore was smelted. Dart (1934) reports crudely flaked mining tools, which had been used as wedges, choppers, chisels and hammer stones at Kabwe, Zambia. Also associated with the aforementioned tools were upper and grinding stones, and a single polished stone axe. About 5 km away from this site, at Kafulamadzi Hills, Stone Age tools together with manganese tools were found, and it was on this basis that Dart (1934) postulated Stone Age and metal working activities in Southern Africa. Tools of Stone Age people who inhabited the Nchanga area in Zambia have been dated at about 4300 BC based on C14 (Clark, 1959) and the remains of copper and iron smelters indicate that Iron Age Bantu lived in the area later (McKinnon & Smit, 1961).

The ancient mining sites in Zambia are closely related to the areas where ore was processed. As discussed above, the main sites are Chondwe, Bangweulu, Kapwirimbwe, Kalundu and Dambwa. It appears that the sites of Chondwe were well situated, as the ore was sourced from the Copperbelt. As the ores of the north-western province of Zambia were yet unknown, it is suggested that the early processing centres were most likely Chondwe, Kalundu, Bangweulu and Dambwa. All these centres were located on water courses or lakes (e.g. Lake Bangweulu) and slag material, artefacts, and implements were found at all these sites. Bellows, similar to those in Figure 3.2 were also found.

The Livingstone and Choma museums have records of the archaeological Dambwa and Kalundu sites that testify to the fact that copper and metallurgical technology was used. Of all the known sites, Kapwirimbwe had excellent specimens such as ingots, which were used as a currency in trading with the Lualaba site in the DRC. The copper ingot (Fig. 3.7) was used as standard currency in the Lualaba, Kapwirimbwe, Bangweulu and probably the Nkope sites, and was so popular and famous that the Zambia National Commercial Bank has adopted its shape as its corporate logo.

Figure 3.7: Copper ingots (forefront) with bellows and a ceramic furnace (background) displayed at the Lubumbashi Museum, DRC.

3.4 Democratic Republic of Congo (DRC)

The Lualaba site in the DRC was a large one, and in the late 18t Century supplied a lot of finished copper jewellery to the east coast of Africa through strong trading ties with the Tipu-Tipu people, whose capital was at Ujiji on the shores of Lake Tanganyika (AdeAjayi & Crowder, 1985). It is assumed that the Lualaba and Kalundu sites may be the most ancient in Sub-Saharan Africa due to the long time of residence associated with these two archaeological centres. The Lualaba sites in the Katanga Province were more active because the Mwata Kazembe Kings actively encouraged trade with the Bisa people of the Bangweulu area in modern day Zambia. The Mwata Kazembe Kings also had links to the Bembe site close to the Angolan border, which was discovered by Portuguese sailors and traders in 1481 in their quest for gold. The Portuguese wrote that (Herbert, 2003):

"we found no gold, but much abundant and fine copper".

Other DRC centres where copper, iron and lead were processed occur at the Niari Djoue mineral fields (Herbert, 2003), located north of the Angolan border close to the Congo River, as well as the Mindouli and M'Boko Songho sites, which had close to 200 pits and are thought to have been centuries old. The word "Songho" means Copper. The Mindouli site was a complex metallurgical site with abundant smelting and slag heaps. These sites are dated to be centuries old (close to 2000 B.C.) and not at all linked to European history on the African continent (Herbert, 2003).

3.5 Summary

In this Chapter it has been shown that copper and iron smelting technologies were active in Sub-Saharan Africa some 2000 years B.C., and iron technology as early as 8000 BC. It has been shown by archaeology, culture and history of the African peoples that copper metal was also alloyed with iron, manganese, lead and zinc to produce instruments of war, culture, beauty, and religion. This evidence dispels the common myth found among some writers that Africans were incapable of large scale metal technology. Satyt, one of the early white explorers is quoted in Herbert (2003) as to having got this first hand explanation from African metal workers:

> The copper-ore was first cobbled into small pieces. The kiln for smelting was prepared by making a small circular impression in the ground, about 1½ feet in diameter, and lining it with clay and ashes; on this base a circular clay wall was built up to a height of 1½ feet and reinforced on the outside with stones. A layer of dry leaves of the *mukwiliri* or *mulamvhira* trees was put into the bottom of this kiln to a depth of about 2 inches to help in the kindling, over this was put a thick layer of charcoal and then more leaves. A small hole was made at the base of the kiln to give entrances to the nozzles of the bellows, and the charcoal was fired; as soon as it was red-hot another layer of copper was added and then a final layer of charcoal until all copper was melted, when the worker proceeded to break down the wall of the kiln. All the debris of dirt, charcoal, and ashes was brushed away, leaving the copper in the clay-lined impression in the ground. The copper was left to cool and then again hammered into small cobbles and resmelted in a potsherd about 7 inches in diameter, which was put over the impression in the ground, so that the molten copper could be manipulated easily and poured out into the moulds prepared for it. The usual moulds were made in the ground with a stick about ½ an inch thick.[27]

This reproduction of the communication by Satyt shows that the methods employed by metal workers in the Transvaal-Zimbabwe area were similar to those employed in the Swaartmodder and Oanob areas of Namibia as shown in Figures 3.3 and 3.4 above. The malleability of the metal made it easy to work with, making copper a favourite metal of choice when making alloys. Copper was valued among the peoples of Katanga in the DRC and Bisa in Zambia as a source of fertility just as ivory was valued by other cultures for the same beliefs (Herbert, 2003).

CHAPTER 4: MODERN COPPER PRODUCTION

4.1 Introduction

Modern copper production follows well established stages that begin with mining of sulphide and/or oxide copper ores from underground or open pit mines and end with production of pure copper cathodes with 99.9% copper. The main production stages involve mining by drilling and blasting, loading, crushing (using surface or underground crushers), transportation to metallurgical plants, grinding in rod- or ball-mills, concentration of sulphide ores by flotation or leaching of oxide ores and tailings, and finally solvent extraction-electrowinning (SX/EW) or smelting and electrolytic refining to produce pure copper cathodes (Fig. 4.1). Thereafter, wire rods, billets, cakes and ingots are manufactured in mills from the cathodes resulting in finished products of pure copper wire from copper rods; tube, rod and bar stock from billets; plate, sheet, strip and foil from cakes; and copper metal alloys from ingots (Copper Development Association, 2009b) for use in various industries, including building construction, electronics, transportation and communication.

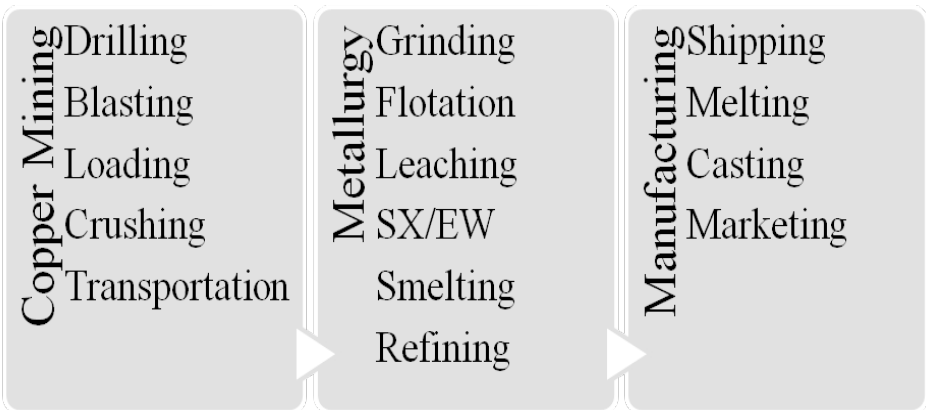


Figure 4.1: Main stages and processes in copper production from mining to manufacturing.

4.2 Copper Mining in Namibia, Zambia and the Democratic Republic of Congo

Modern copper mining can be said to have started with the advent of colonialism in Southern and Central Africa when numerous copper occurrences were located with the aid of Africans and explored by Europeans at the beginning of the 20th century. Most of these copper occurrences, e.g. Tsumeb in Namibia (Schneider & Seeger, 1992), Bwana Mkubwa and Kansanshi in Zambia (Gunning, 1961) and Etoile du Congo in DRC (Angermeier et al., 1974) were previously worked by Africans who widely used copper as a medium of exchange and in ornaments.

After about 300 years of exploration and modest exploitation by the Portuguese, the British South Africa Company led by Cecil Rhodes intensified European mining activity in Africa in the late 19th and early 20th centuries, resulting in the location of more than 100 old copper workings by the end of 1906 on the Copperbelt (Gunning, 1961). The Matchless Mine in Namibia (Fig. 4.2) was probably the earliest mine to be operated on a large scale from 1840 to 1862 by the Walwich Bay Copper Mining Company when hand sorted ore was exported to Okiep in South Africa (Schneider & Seeger, 1992).

Continuous copper production in Southern and Central Africa began in 1906 and has contributed significantly to the production of 65 Mt of copper metal valued at US$231 billion (Table 4.1) between 1907 and 2007 based on constant 1998 U.S. dollar copper prices compiled by the U.S. Geological Survey (2008). Over this period the major African copper producing countries have been Zambia (50.3%), DRC (30.9%), South Africa (12.1%) and Namibia (2.8%). Zambia, the DRC and Namibia have produced a combined total of 54.62 Mt of copper metal worth US$195.944 billion, which represents 84.8% of the total value of copper produced in Africa up to 2007.

Figure 4.2: Entrance to the old Matchless Mine, Namibia.

4.3 Copper Production in Namibia

Copper production in Namibia for the period 1907 to 2006 is shown in Figure 4.3, during which period 1.808 Mt of copper metal were produced (Table 4.1) mainly from the Tsumeb, Kombat, Matchless, Otjihase and Klein Aub mines. The annual production together with the value of the copper produced in constant 1998 US$ metal prices over the same period are provided in Table 4.2. Prior to this period an unspecified amount of copper ore was mined at the Matchless Mine from 1840 to 1862 and exported as hand sorted ore to Okiep in South Africa (Schneider & Seeger, 1992). Copper mining from the Tsumeb Mine, the major producer of copper in Namibia, started as early as 1905 (Schneider & Seeger, 1992). Other early copper producers include the Khan and

Table 4.1. Copper mine production in Africa from 1907 to 2007. Based on production data compiled from U.S. Geological Survey Minerals Yearbooks (1928-33 to 2007), Mendelsohn (1961), Ministere Des Mines et Des Affaires Foncieres (n.d.) and Schneider and Seeger (1992) with the US$ value based on constant 1998 copper metal prices (U.S. Geological Survey, 2008).

Country	Period		Years in	Total Mine	Value
	From	To	Production	Production	(98US$)
Algeria	1928	1984	45	19,127.1	77,376,259
Angola	1942	1970	22	23,045.9	89,312,161
Botswana	1973	2006	34	728,082.4	2,019,788,430
Congo	1961	1988	32	21,273.8	77,815,305
DRC	**1911**	**2006**	**96**	**20,100,937.4**	**72,218,079,548**
Ethiopia	1973	1976	4	1,524.1	7,268,833
Kenya	1968	1975	8	556.1	2,666,555
Mauritania	1971	1978	10	104,385.0	490,071,522
Morocco	1929	2006	67	420,666.6	1,263,338,305
Mozambique	1970	1994	19	4,912.9	19,346,886
Namibia	**1907**	**2006**	**89**	**1,808,210.5**	**6,436,842,961**
South Africa	1928	2006	79	7,843,090.2	26,361,535,526
Tanzania	1950	2006	18	30,117.3	34,805,967
Uganda	1956	1977	22	298,482.1	1,266,174,113
Zambia	**1918**	**2007**	**81**	**32,711,643.0**	**117,289,145,023**
Zimbabwe	1928	2006	71	879,692.7	3,351,864,152
Total				64,995,747.3	231,005,431,550

Guchab-Rogerberg mines which started production in 1908, but continuous production of copper in Namibia was interrupted by the two world wars and the world economic recession in the 1930s. After the Second World War copper production in Namibia increased steadily to reach the peak production period between 1975 and 1988 (Fig. 4.3) when an average of 44,575 tonnes of copper metal was produced annually.

The production levels of copper in Namibia are much lower than those observed in Zambia and the DRC (see below) due to the relatively smaller size of the hydrothermal deposits such as Tsumeb and Kombat in comparison to the stratiform copper deposits of the Copperbelt.

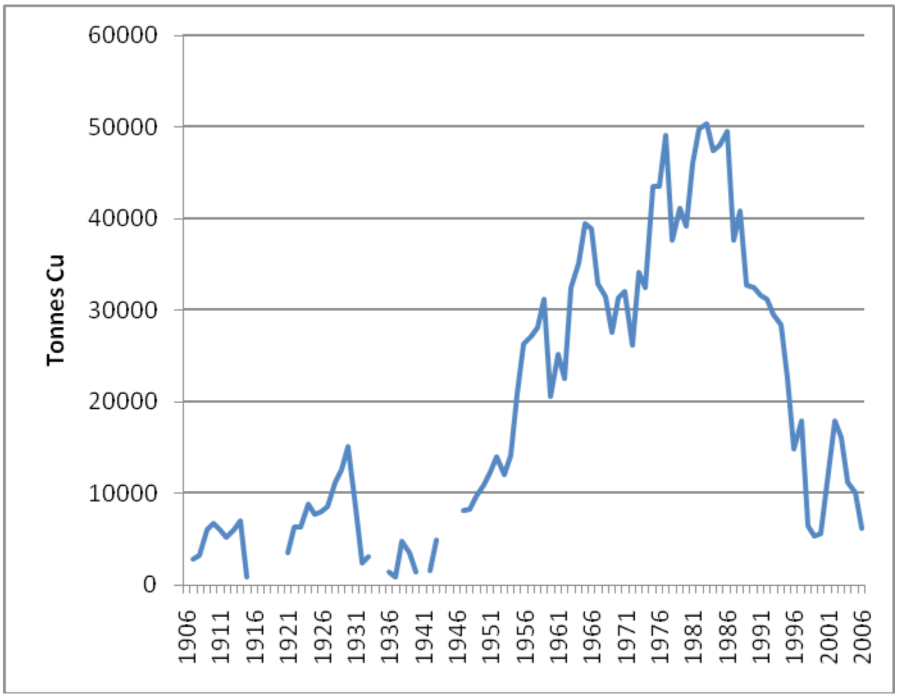


Figure 4.3: Copper Mine production in Namibia (1907 to 2006). Based on data computed from U.S. Geological Survey Mineral Yearbooks (1928-33, 2007) and from Schneider and Seeger (1992).

Whereas the Tsumeb and Kombat deposits represent hydrothermal type mineralization, the Matchless and Otjihase deposits are volcanogenic massive sulphide ores associated with mafic volcanism. The sediment-hosted Klein Aub deposit, which produced 5.5 Mt tonnes of Cu ore grading at 2% Cu and 50 g/t Ag between 1966 and 1987 (Borg, 1995), is comparable to copper deposits in the DRC-Zambia Copperbelt.

Table 4.2: Copper metal production in Namibia for the period 1907 to 2006 (based on data compiled from U.S. Geological Survey Minerals Yearbooks (1928-33 to 2007); Schneider & Seeger (1992); Mines Directorate (2000)). US$ values based on U.S. Geological Survey (2008) constant 1998 copper metal prices; nd = no data available.

Year	Tonnes Cu	Value (US$98)	Year	Tonnes Cu	Value (US$98)	Year	Tonnes Cu	Value (US$98)
1907	2,850	21,945,000	**1941**	Nd		**1975**	43,551	186,614,321
1908	3,210	17,013,000	**1942**	1,609	4,263,850	**1976**	43,500	191,095,500
1909	6,032	31,969,600	**1943**	5,000	12,500,000	**1977**	49,200	194,832,000
1910	6,771	33,855,000	**1944**	Nd		**1978**	37,700	136,662,500
1911	6,090	29,841,000	**1945**	Nd		**1979**	41,100	187,621,500
1912	5,212	32,314,400	**1946**	Nd		**1980**	39,200	173,224,800
1913	6,106	34,376,780	**1947**	8,100	27,702,000	**1981**	46,100	153,420,800
1914	7,078	33,691,280	**1948**	8,270	27,456,400	**1982**	49,800	135,007,800
1915	878	5,426,040	**1949**	9,622	28,288,680	**1983**	50,400	139,154,400
1916	nd		**1950**	10,961	35,184,810	**1984**	47,400	109,636,200
1917	nd		**1951**	12,335	41,939,000	**1985**	48,000	107,424,000
1918	nd		**1952**	14,022	46,414,144	**1986**	49,600	107,384,000
1919	nd		**1953**	12,117	47,378,643	**1987**	37,600	98,098,400
1920	nd		**1954**	14,159	56,637,600	**1988**	40,900	149,775,800
1921	3,510	8,915,400	**1955**	20,900	105,334,992	**1989**	32,800	124,541,600
1922	6,398	18,554,200	**1956**	26,290	145,648,816	**1990**	32,500	109,947,500
1923	6,280	19,468,000	**1957**	27,134	104,194,944	**1991**	31,700	91,454,500
1924	8,812	24,585,480	**1958**	28,100	92,168,656	**1992**	31,300	86,106,300
1925	7,746	22,618,320	**1959**	31,240	119,336,800	**1993**	29,500	67,201,000
1926	8,024	22,788,160	**1960**	20,591	80,714,760	**1994**	28,400	76,452,800
1927	8,584	23,090,960	**1961**	25,200	91,475,637	**1995**	22,530	73,492,860
1928	11,300	35,143,000	**1962**	22,563	82,805,109	**1996**	14,845	37,082,810
1929	12,600	48,510,000	**1963**	32,454	118,131,832	**1997**	17,879	42,820,205
1930	15,100	43,186,000	**1964**	35,106	131,649,000	**1998**	6,500	11,271,000
1931	8,400	16,632,000	**1965**	39,423	158,480,460	**1999**	5,360	8,779,680
1932	2,480	3,769,600	**1966**	38,934	155,346,660	**2000**	5,620	10,346,420
1933	3,112	6,286,644	**1967**	32,888	134,840,800	**2001**	12,393	19,320,687
1934	nd		**1968**	31,471	134,067,738	**2002**	18,012	27,270,168
1935	nd		**1969**	27,624	128,423,511	**2003**	16,175	26,931,375
1936	1,381	3,480,120	**1970**	31,393	168,738,988	**2004**	11,174	28,471,352
1937	907	3,038,450	**1971**	32,039	148,117,222	**2005**	10,157	32,421,144
1938	4,828	12,601,080	**1972**	26,154	115,602,006	**2006**	6,262	35,129,820
1939	3,530	10,237,000	**1973**	34,168	164,384,172			
1940	1,485	4,395,600	**1974**	32,479	182,890,375			

The closed Tsumeb Mine was a major producer of Cu, Pb and Zn from 1906 to 1996 from a total tonnage of 30 Mt grading 10.45% Pb, 4.42%Cu, 3.49% Zn, and 125g/t Ag, whereas the recently closed Kombat Mine had total reserves of 18.5 Mt with relatively lower grades of 2.14% Pb, 2.79% Cu, 1.5% Zn and 25 g/t Ag (Kamona & Günzel, 2007). The mineralization at Tsumeb is confined to an ellipsoidal structure on the northern limb of a large syncline, cutting through the uppermost carbonate members of the Tsumeb Subgroup, and reaching a depth of 1400 m below surface. Sulphide ore replaces a feldspathic sandstone representing the infill of a karst-induced breccia pipe, and the host dolostone as manto ores. Due to complex hydrological conditions, sulphide ores have been oxidized to great depth, producing spectacular secondary mineral specimens of Cu-Zn-Pb carbonates, sulphates, arsenates, vanadates, oxides and silicates. Tsumeb Mine was closed in 1996 due to exhaustion of reserves.

The Kombat Mine in the southern part of the OML is hosted within the upper carbonate units of the Tsumeb Subgroup and consists of several vertical orebodies that terminate at the contact with overlying slates. Massive to semi-massive sulphide ore is best developed in zones of brecciation within dolostone and associated feldspathic sandstone lenses. The ore consists of chalcopyrite, bornite, galena, chalcocite, minor sphalerite, tennantite, betechthinite, arsenopyrite, enargite, renierite and colusite (Innes & Chaplin, 1986; Kamona & Günzel, 2007). The presence of stratiform Fe-Mn oxide/silicate beds within zones of tectonic transposition is a feature unique to the deposits in the OML. Kombat Mine ceased operations in 2006 due to flooding of the underground mine workings.

The sulphide ores were concentrated at the respective mine plants whereas smelting to produce copper cathodes was done at the only smelter in Namibia at Tsumeb. This smelter is still operational, but currently processes concentrates from abroad (DRC, Zambia, Mauritania and Chile). Underground development and mining at the stratiform Tschudi copper deposit, which started in 2008, was stopped in December 2008 due to the current economic downturn with copper prices below US$3,000 per tonne.

4.4 Copper Production in Zambia

Zambia is the largest single producer on the African continent and it has produced a total of 32.711 Mt of copper metal worth US$117.289 billion since 1918 (Tables 4.1, 4.3) at an annual average production of 403,847 t copper. Copper production in Zambia first started with underground mining at the Bwana Mkubwa Mine in 1913, but a change was made to open pit mining in 1925 (Pienaar, 1961). Bwana Mkubwa closed down in 1931 (during the world economic depression) after having producing 22,352 metric tonnes at a loss (Mendelsohn, 1961). Luanshya Mine (previously Roan Antelope) was the first major producer of copper on the Copperbelt when the mine came into operation in 1931 (Mendelsohn, 1961). At independence in October 1964, the British South Africa Company, which had received royalties on copper under mineral rights dating back to 1889, yielded its mineral rights at a fee (U.S. Geological Survey, 1964).

Table 4.3: Copper metal production in Zambia for the period 1918 to 2007 (based on data compiled from U.S. Geological Survey Minerals Yearbooks (1928-33 to 2008); Mendelsohn (1961)). Calculated US$ values based on constant 1998 copper metal prices (U.S. Geological Survey, 2008); nd = no data available.

Year	Tonnes Cu	Value (US$98)	Year	Tonnes Cu	Value (US$98)	Year	Tonnes Cu	Value (US$98)
1918	2,891	17,025,045	**1948**	225,472	748,567,040	**1978**	643,000	2,330,875,000
1919	nd		**1949**	258,054	758,678,760	**1979**	588,300	2,685,589,500
1920	nd		**1950**	297,437	954,772,770	**1980**	605,800	2,677,030,200
1921	nd		**1951**	319,373	1,085,868,200	**1981**	578,000	1,923,584,000
1922	nd		**1952**	328,482	1,087,276,413	**1982**	666,800	1,807,694,800
1923	nd		**1953**	372,681	1,457,182,319	**1983**	541,000	1,493,701,000
1924	nd		**1954**	397,992	1,591,969,600	**1984**	531,700	1,229,822,100
1925	nd		**1955**	359,128	1,810,002,600	**1985**	458,600	1,026,346,800
1926	nd		**1956**	404,122	2,238,837,542	**1986**	461,400	998,931,000
1927	nd		**1957**	435,735	1,673,223,168	**1987**	462,000	1,205,358,000
1928	6,026	18,740,860	**1958**	400,137	1,312,449,688	**1988**	431,800	1,581,251,600
1929	5,603	21,571,550	**1959**	543,257	2,075,242,122	**1989**	465,600	1,767,883,200
1930	8,630	24,681,800	**1960**	576,363	2,259,343,744	**1990**	436,300	1,476,002,900
1931	32,923	65,187,540	**1961**	574,738	2,086,297,125	**1991**	390,600	1,126,881,000
1932	88,839	135,035,280	**1962**	562,327	2,063,740,824	**1992**	429,500	1,181,554,500
1933	131,600	265,832,000	**1963**	588,121	2,140,761,532	**1993**	428,300	975,667,400
1934	160,123	373,086,590	**1964**	632,353	2,371,324,125	**1994**	373,200	1,004,654,400
1935	171,800	400,294,000	**1965**	685,124	2,754,198,480	**1995**	316,000	1,030,792,000
1936	173,468	437,139,360	**1966**	624,220	2,490,637,800	**1996**	334,000	834,332,000
1937	249,835	836,947,250	**1967**	700,302	2,871,238,200	**1997**	352,900	845,195,500
1938	234,904	613,099,440	**1968**	710,249	3,025,660,740	**1998**	315,000	546,210,000
1939	215,065	623,688,500	**1969**	748,122	3,478,016,854	**1999**	280,000	458,640,000
1940	205,000	606,800,000	**1970**	684,112	3,677,102,000	**2000**	249,100	458,593,100
1941	231,910	679,496,300	**1971**	651,399	3,011,416,190	**2001**	312,000	486,408,000
1942	250,564	663,994,600	**1972**	717,703	3,172,249,028	**2002**	341,000	516,274,000
1943	254,410	636,025,000	**1973**	706,668	3,399,781,672	**2003**	348,000	579,420,000
1944	225,688	552,935,600	**1974**	687,980	3,874,016,506	**2004**	426,900	1,087,741,200
1945	197,192	475,232,720	**1975**	676,924	2,900,620,626	**2005**	447,000	1,426,824,000
1946	185,607	478,866,060	**1976**	708,900	3,114,197,700	**2006**	514,000	2,883,540,000
1947	197,288	674,724,960	**1977**	656,000	2,597,760,000	**2007**	520,000	2,956,200,000

During the Second World War, Zambia was among the five major copper producers (others being the USA, Chile, Canada and then Belgian Congo (now DRC) with record or near record productions in 1942. Copper production from these countries was all directed towards filling the Allied Nations war effort (USGS, 1942). Peak annual copper production of above 400,000 tonnes was first achieved in Zambia from 1956 to 1993 when an average of 537,515 tonnes of copper metal were produced annually with an all time record production of 748,122 tonnes in 1969 (Table 4.3; Fig. 4.4). Since 1993, copper production has declined to reach a post-independence low of 249,100 tonnes in 2000. However, production has once again increased to above 500,000 tonnes since 2006 (Table 4.3; Fig. 4.4).

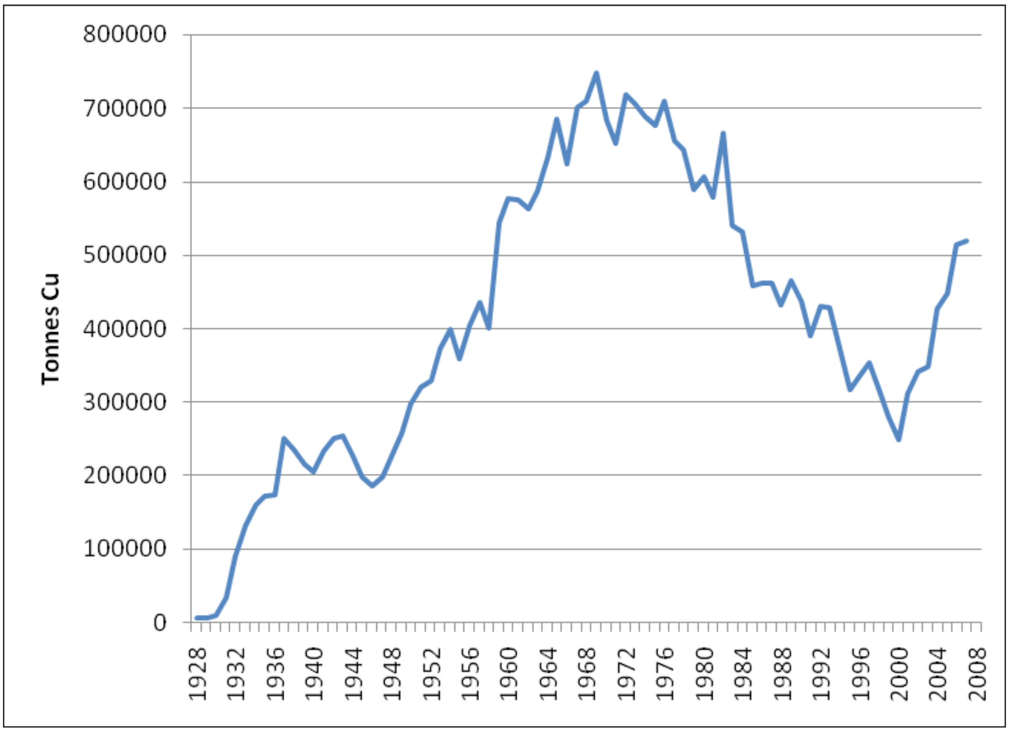


Figure 4.4: Copper production in Zambia from 1928 to 2007. Based on data computed from U.S. Geological Survey Mineral Yearbooks (1928-33, 2008).

The major copper producers in Zambia are Nkana, Mufulira, Nchanga, Luanshya and Konkola (Fig. 4.5). Copper production from these mines (Mendelsohn, 1961) began in 1929 (Nkana and Mufulira), 1931 (Luanshya), 1937 (Nchanga) and 1957 (Konkola), respectively. Each major mine has its own ore processing plants (concentrator and smelter) to produce copper cathodes. Electrolytic refining to produce electrolytic copper is done at Ndola and Nkana where precious metals (Au, Pt, Ag) are recovered.

The Lumwana Copper Project of Equinox Minerals Limited, an Australian/Canadian company, was expected to be commissioned in mid-2008. Lumwana, with reserves of 321 Mt averaging 0.73% Cu, is reputed to be Africa's largest copper mine (Equinox Minerals, 2008). Equinox Minerals will mine an average of 20 Mt annually to produce 122,000 t of copper each year over the estimated 37 years of mine life.

4.5 Copper Production in the DRC

The DRC is the second largest copper producer in Africa with a total production of 20.101 Mt worth US$72.218 billion since 1911 (Tables 4.1, 4.4) at an average production rate of 209,385 t of copper annually. Peak copper production in the DRC occurred between 1971 and 1990 (Fig. 4.5).

Modern copper production in the Katanga Province of the DRC (Fig. 4.5) started in 1911 with open pit mining of the "Etoile du Congo" also known as "Kalukuluku", a deposit which was worked by the indigenous Africans prior to the arrival of the Europeans (Angermeier et al., 1974). Kalukuluku contained 6% Cu and was closed in the early 1960's due to exhaustion of the reserves. Kambove, which was the first underground mine to be exploited in 1913, also contributed much copper from open pit mining, including 962,700 t of ore with 4.5 % Cu in 1971 (Angermeier et al., 1974). Likasi is another deposit which produced copper in the early years from 1918 to 1929 when it was closed.

Table 4.4: Copper metal production in the DRC for the period 1911 to 2006. Based on data compiled from Ministere Des Mines et Des Affaires Foncieres (n.d.) and the U.S. Geological Survey Minerals Yearbooks (1928-33 to 2007) with calculated US$ values based on constant 1998 copper metal prices (U.S. Geological Survey, 2008).

Year	Tonnes Cu	Value (US$98)	Year	Tonnes Cu	Value (US$98)	Year	Tonnes Cu	Value (US$98)
1911	998	4,890,200	**1943**	156,850	392,125,000	**1975**	496,334	2,126,789,476
1912	2,492	15,450,400	**1944**	165,484	405,435,800	**1976**	444,400	1,952,249,200
1913	7,407	41,701,410	**1945**	160,211	386,108,510	**1977**	481,600	1,907,136,000
1914	10,722	51,036,720	**1946**	143,885	371,223,300	**1978**	423,800	1,536,275,000
1915	14,042	86,779,560	**1947**	150,840	515,872,800	**1979**	400,000	1,826,000,000
1916	22,167	207,483,120	**1948**	155,515	516,309,800	**1980**	539,500	2,384,050,500
1917	27,462	224,913,780	**1949**	141,399	415,713,060	**1981**	555,100	1,847,372,800
1918	29,238	172,211,820	**1950**	175,920	564,703,200	**1982**	519,000	1,407,009,000
1919	23,019	87,011,820	**1951**	191,959	652,660,600	**1983**	536,500	1,481,276,500
1920	18,962	59,540,680	**1952**	205,749	681,029,190	**1984**	562,000	1,299,906,000
1921	30,464	77,378,560	**1953**	214,116	837,193,560	**1985**	557,900	1,248,580,200
1922	43,362	125,749,800	**1954**	223,791	895,164,000	**1986**	525,800	1,138,357,000
1923	57,886	179,446,600	**1955**	235,089	1,184,848,560	**1987**	512,600	1,337,373,400
1924	85,570	238,740,300	**1956**	249,964	1,384,800,560	**1988**	494,200	1,809,760,400
1925	90,104	263,103,680	**1957**	242,244	930,216,960	**1989**	465,500	1,767,503,500
1926	80,639	229,014,760	**1958**	237,561	779,200,080	**1990**	413,000	1,397,179,000
1927	89,156	239,829,640	**1959**	282,094	1,077,599,080	**1991**	265,000	764,525,000
1928	112,456	349,738,160	**1960**	302,297	1,185,004,240	**1992**	168,000	462,168,000
1929	136,992	527,419,200	**1961**	295,237	1,071,710,310	**1993**	46,300	105,471,400
1930	138,949	397,394,140	**1962**	296,996	1,089,975,320	**1994**	30,000	80,760,000
1931	120,186	237,968,280	**1963**	270,781	985,642,840	**1995**	29,400	95,902,800
1932	54,064	82,177,280	**1964**	276,666	1,037,497,500	**1996**	50,000	124,900,000
1933	66,596	134,523,920	**1965**	288,504	1,159,786,080	**1997**	39,651	94,964,145
1934	110,085	256,498,050	**1966**	315,664	1,259,499,360	**1998**	34,994	60,679,596
1935	107,682	250,899,060	**1967**	318,976	1,307,801,600	**1999**	32,000	52,416,000
1936	95,667	241,080,840	**1968**	324,502	1,382,378,094	**2000**	21,000	38,661,000
1937	150,588	504,469,800	**1969**	356,908	1,659,263,432	**2001**	20,988	32,720,292
1938	123,943	323,491,230	**1970**	385,681	2,073,034,838	**2002**	40,000	60,560,000
1939	122,649	355,682,100	**1971**	405,831	1,876,154,402	**2003**	59,000	98,235,000
1940	148,804	440,459,840	**1972**	428,201	1,892,647,978	**2004**	73,000	186,004,000
1941	162,167	475,149,310	**1973**	488,569	2,350,505,459	**2005**	97,000	309,624,000
1942	165,940	439,741,000	**1974**	499,430	2,812,289,767	**2006**	130,000	729,300,000

Mining of copper in the DRC is from both carbonate- and siliciclastic hosted deposits in rocks. The siliciclastic hosted ores, e.g. Musoshi and Kinsenda, are similar to the Zambian deposits, whereas the carbonate-hosted ores are associated with breccias interpreted as tectonic (Cailteux et al., 2005b) or synsedimentary (Wendorff, 2003). However, the main copper minerals in both the carbonate- and siliciclastic-hosted deposits are similar and comprise variable proportions of chalcopyrite, bornite, digenite, covellite, and chalcocite with linnaite and carrolite as the associated cobalt-bearing minerals.

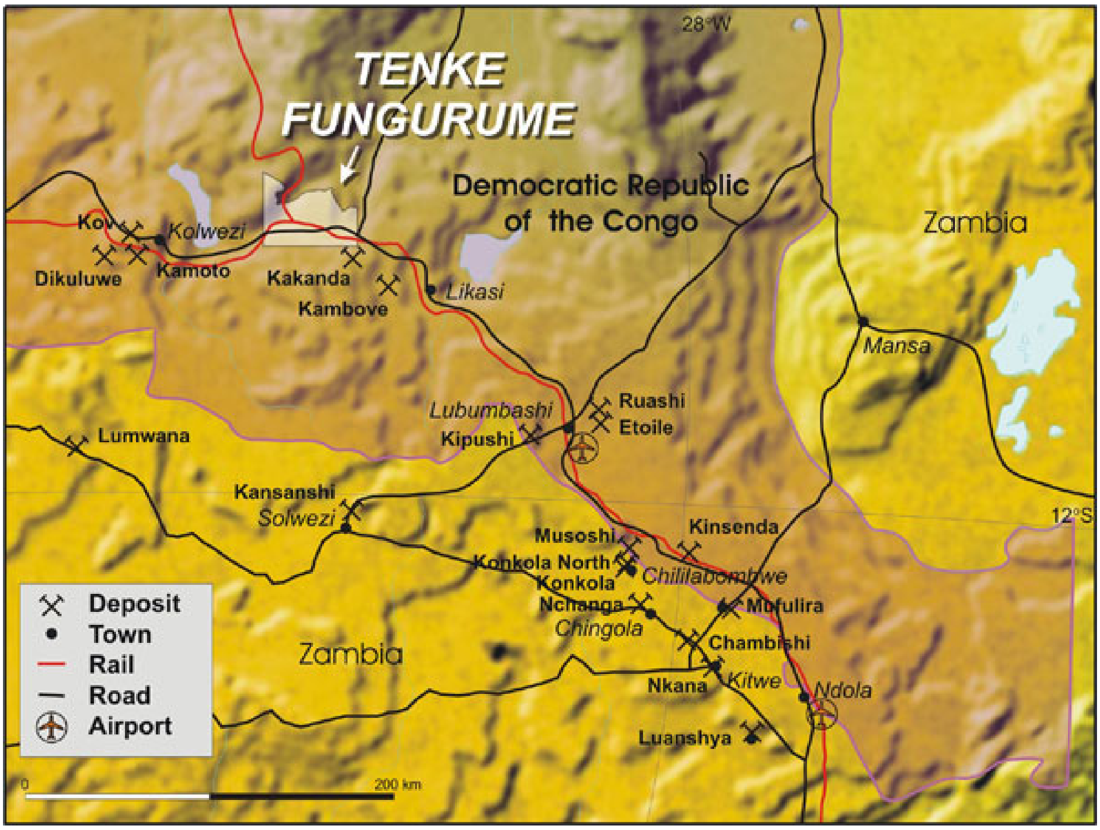


Figure 4.5: Location map of copper deposits in Zambia and the DRC.

Production of copper increased steadily from 1911 to reach a peak of 488,569 tonnes in 1973 and the record high of 562,000 tonnes in 1984 (Fig. 4.6). The overall period of peak copper production is from 1971 to 1990 when production fluctuated between 400,000 and 562,000 tonnes with an average of 487,463 tonnes of copper metal. Apart from the early years of copper mining from 1911 to 1928, during which time annual copper production was below 100,000 tonnes, low levels of production were also experienced from 1932 to 1933 during the world economic depression and recently from 1993 to 2005. However, since 2006 copper production has started to rise above 100,000 tonnes (Fig. 4.6).

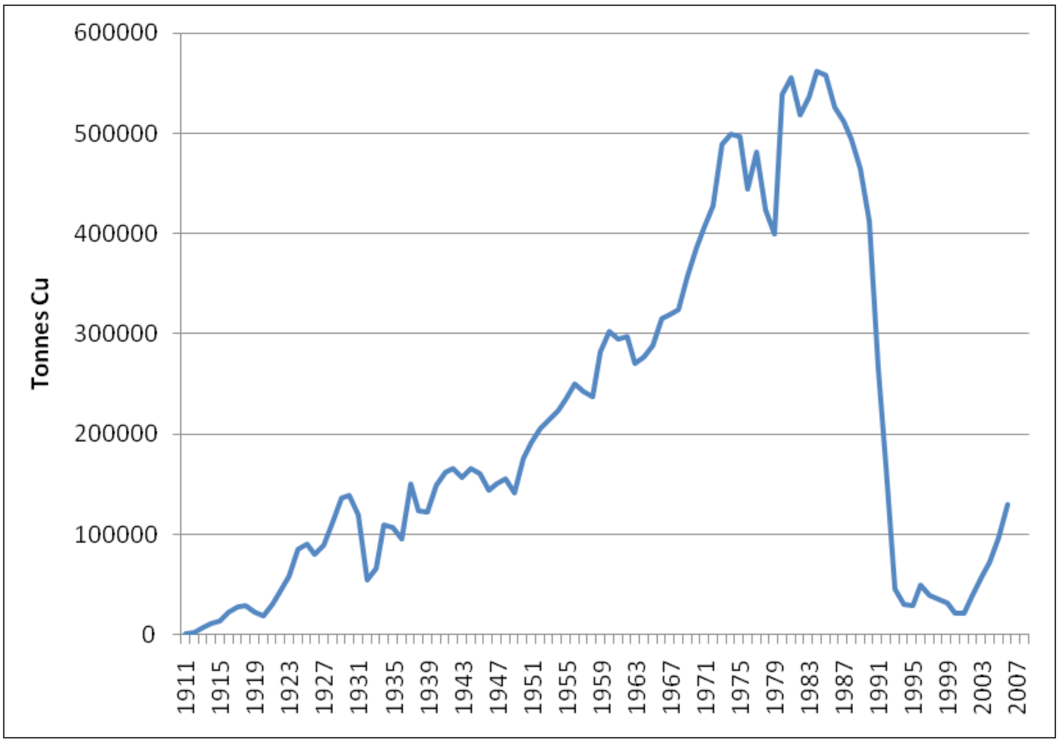


Figure 4.6: Copper metal production in the DRC from 1911 to 2006 (based on data compiled from annual reports of the U.S. Geological Survey (1928-1933 to 2007) and the Ministere Des Mines et Des Affaires Foncieres (n.d.).

The copper produced in the DRC has come from deposits which vary from copper rich (e.g. Musoshi, Kolwezi, Kisenda) to polymetallic deposits in which copper is associated with cobalt (e.g. Etoile du Congo, Luiswishi, Ruwe), lead, zinc and silver (e.g. Kipushi, Kengere), uranium (e.g. Kambove, Kamoto, Shinkolobwe) and silver (e.g. Dikulushi, Likasi). In addition, some deposits may contain vanadium and platinum (e.g. Ruwe, Shinkolobwe) as well as gold (Musonoi, Ruwe) or nickel (Shinkolobwe) (Baud, 1964).

Musonoi and Kamoto were among the two most important mines in Katanga with Musonoi producing about 50% of the copper and 80% of the cobalt annually up to the end of the 1950s. Kamoto, with an annual open pit production of 3 Mt of copper ore averaging 5% Cu and 0.4% Co from oxide and sulphide ores as well as an underground mining capacity of 1.8 Mt of ore from 1972, was the largest mine belonging to “La Generale des Carrieres et Mines du Zaire” (Gècamines), a state owned company in Katanga since the early 1950s (Angermeir et al., 1974). Musoshi and Kinsenda, which came into production in the early 1970s, are the two major mines in the southern part of the Copperbelt near the border with Zambia (Fig. 4.5).

Metallurgical processing (concentration by flotation and leaching, smelting and refining) of the copper ore to produce copper metal has been carried out in various plants, including Kamoto, Kolwezi, Luilu, Shituru and Lubumbashi. Much of the copper of the 1971 to 1990 peak production came from the Kamoto Mine which had two flotation plants of 1.8 and 3.6 Mt, respectively. Most of the earlier production was processed at the Kolwezi Plant, which was opened in 1941/42 with a capacity of 4 Mt. The concentrates were transported by rail for metal production at the Luili and Shituru plants which had annual capacities of 125,000 and 150,000 t of electrolytic copper, respectively as well as the Lubumbashi Plant (115,000 t of blister copper) in the early 1970s (Angermeir et al., 1974).

The future outlook of copper mining in the DRC remains bright with extensive high-grade mineral resources such as Tenke-Fungumire (547 Mt grading 3.5% Cu and 0.27% Co; Engineering and Mining Journal, 2000) still to be developed for full scale production. Tenke-Fungurume was first explored by Union Minière du Haut Katanga in 1918, but it was never brought into production owing to a lack of suitable technology.

CHAPTER 5: IMPACT OF COPPER PRODUCTION TO LOCAL ECONOMIES AND THE ENVIRONMENT IN NAMIBIA, ZAMBIA AND THE DEMOCRATIC REPUBLIC OF CONGO

5.1 Introduction

As discussed earlier, copper production influenced the local economies of indigenous people who produced and traded items such as copper bracelets, anklets, ingots and various tools before the onset of colonialism in Namibia, Zambia and the DRC. Copper bangles and necklaces were prized possessions in prehistoric and pre-colonial periods (Gebhard, 1999), whereas copper ingots were used as a form of currency and powdered malachite was used for medicine (Mendelsohn, 1961). The indigenous miners were attracted to areas where copper deposits were exposed at the surface in the form of secondary minerals such as malachite and azurite, which they were able to smelt since copper sulphide smelting technology was not yet known in pre-colonial times.

The immediate benefit of copper smelting during pre-colonial times was the production of small tools and ornaments that were either used locally or traded regionally and even internationally in exchange for other commodities such as livestock, iron implements, salt, beads, tobacco and cloth (e.g. Sharpe, 1962; Kinahan, 1980). The mining, smelting and trade in copper and other metals contributed to the development of urban centres and the concentration of power in the major ancient mining sites (Miller et al., 2005) of southern and central Africa.

The trade in copper attracted the first Europeans who travelled through Sub-Saharan Africa in search of mineral resources (e.g. Gebhard, 1999; Mendelsohn, 1961). The early European prospectors and explorers were led to some of the ancient workings by local Africans, resulting in the location and discovery of major mineral deposits such as Sinclair, Klein Aub and Tsumeb in Namibia (Kuntz, 1904; Rimann, 1915; Gebhard, 1999); Bwana Mkubwa and Roan Antelope in Zambia (Mendelsohn, 1961) as well as many orebodies in the DRC (Henry & Wilson, 2006).

The modern era of copper mining on the Katangan Copperbelt began in 1910 with the opening of Bwana Mkubwa although mining in general had already started in 1902 at Kabwe (Broken Hill) in central Zambia. Kabwe is a special case because its discovery and mining enticed Cecil Rhodes to extend the main railway line from Bulawayo in Southern Rhodesia (Zimbabwe) to Kabwe where zinc and lead ores were being mined. From Broken Hill, the railway line was extended further to Bwana Mkubwa on the Copperbelt and onwards into the Belgian Congo. The construction of this railway line made transportation of ores and metals to Europe and South Africa possible, since much more ore could be transported cheaply and effectively.

5.1.1 Economic overview of Namibia, Zambia and the DRC

5.1.1.1 Namibia

Namibia has a land area of 825,418 sq. km and an economy which is heavily dependent on mineral exports, particularly gem-quality diamonds, uranium, copper, lead, zinc, gold, silver and fluorspar. Mining in Namibia accounted for 12.4 % of GDP in 2007, and provides more than 50% of foreign exchange earnings. Despite a high per capita GDP of USD $5,500, relative to the region, Namibia has one of the world's most unequal income distributions.

With the closure of the copper mining operations at Otjihase, Tschudi and Tsumeb West in November 2008 by Weatherly International, copper production is currently at a standstill. However, Weatherly continues to operate the Tsumeb copper smelter, which it acquired from the Namibian mining and smelting company Ongopolo in July 2006, along with Ongopolo's other mining assets (Kombat, Matchless, Tschudi and Tsumeb). The Tsumeb smelter is one of only four commercial smelters in Africa and produces 98.6% pure blister copper (containing gold and silver for which a credit is given upon sale) at an annual capacity of 24,000 t (Weatherly, 2008). Weatherly has invested in a two phase expansion programme to increase annual capacity to 50,000 t. However, this target may only be achieved through imports of copper concentrates from external sources, namely Bulgaria, Peru, the DRC, Chile, Mauritania, South Africa and Zambia, as the Namibian production is currently zero.

New investors are currently negotiating with Weatherly International to take over the closed mines. Other copper deposits with a future potential, depending on world copper prices, include (Geological Survey of Namibia, 2006): Ongombo (3.29 Mt, 1.9% Cu), Onganja (300,000 t, 2% Cu), Klein Aub (7.5 Mt, 2% Cu, 50 ppm Ag) and the Witvlei copper deposits at Malachite Pan (2.98 Mt, 2.1% Cu; with a zone of supergene enrichment of about 280,000 t at 2.76% Cu) and Witvlei Pos (9.5 Mt, 1.5% Cu). In addition, Mintek (South Africa) has conducted tests on the Haib copper porphyry deposit in southern Namibia to extract copper by chemical and bacterial leaching processes. The Haib copper deposit contains an ore reserve of 244 Mt at a grade of 0.37% Cu, using a cut-off grade of 0.3% Cu (Copper Resources Corporation, 2005).

Another future source of revenue for Namibia is expected to be provided by the recovery of metals from the Tsumeb Smelter slag stockpiles. The Tsumeb slags were often rich in residue metals, especially Pb, Zn and Cu as well as the rare metals Ge, Ga and In, which were not fully recovered during the smelting processes. Emerging Metals Limited is planning to process the two smelter slag stockpiles at Tsumeb which contain metal grades of (Emerging Metals, 2008): 6.4 to 11.63% Zn, 1.5 to 2.7% Pb and 70 to 590 ppm Ge in the Lead Blast Furnace Slag; and 1.82 to 7.88% Zn, 0.16 to 4.41% Pb, and 110 to 1300 ppm Ge in the Copper Reverbatory Furnace Slag stockpiles. According to Emerging Metals (2008), the Lead Blast Furnace Slag Stockpile contains 2.0 Mt with reported average grades of 260 ppm Ge and 9.03% Zn as an Indicated Resource. No tonnage or grade information is available for the Copper Reverbatory Furnace Slag Stockpile.

5.1.1.2 Zambia

Zambia, a landlocked country covering an area of 752,612 km2, is richly endowed with metals such as copper, cobalt, zinc, lead, coal, gold, uranium, various precious stones (amethyst, aquamarine and emerald) and hydroelectric power. The country also has extensive arable land, forests, woodlands and water resources. In 2007 Zambia's GDP (current prices) was US$ 11.4 billion, with an annual growth rate (2008, preliminary) of 6% and a per capita GDP (2006, current prices) of US$ 956 (USAGOV, 2009).

Zambia´s earliest evidence for mining is some 28,000 years old, the country has been systematically mining for more than 1,000 years, and has been an exporter of refined copper to Asia, the Middle East and Europe for at least 400 years (SADC Review, 2008). While the mining sector currently only employs 63,000 people, it contributes around 70% of exports and 4% of GDP (African Economic Outlook, 2008). Mining companies are also engaged in development projects in the area of health and agriculture. However, other sectors now make significant contributions to the country's GDP as indicated by the 2006 estimates for agriculture, forestry and fisheries (20.7%), wholesale and retail trade (17.7%), construction (12.9%) and manufacturing (10.5%) (African Economic Outlook, 2008).

Under British colonial rule the mines in Zambia (then Northern Rhodesia) were owned by Roan Selection Trust (RST) and Anglo-American Corporation (AAC). However, Comrade Kenneth Kaunda, the first Zambian President who came to power in October

1964, was concerned about the lack of reinvestment into the Zambian economy by the two mining companies, and in 1969 the Zambian government consequently nationalised the mines. All mineral rights reverted to the state and RST and AAC were forced to give 51% of shares in all existing mines to the state (Fraser & Lungu, 2007). In 1982 the nationalised companies were combined to form Zambia Consolidated Copper Mines (ZCCM) Limited, which managed the mines until the early 1990s when the mines were privatised under the government of President Chiluba who took over power from Comrade Kaunda in 1991.

Privatisation of the ZCCM copper mines soon resulted in investments in plant rehabilitation, expansion and increased exploration. However, AAC, the second-largest shareholder in Zambia's largest mine, Konkola Copper Mines (KCM), pulled out in 2002, and it was replaced by Vedanta Resources (Great Britain). Other leading investors in Zambia's mining industry are (USAGOV, 2009): Glencore International (Switzerland), which invested in new smelting and matte-settling furnaces, a sulphuric acid plant, an oxygen plant and also upgraded the associated infrastructure at Mopani Copper Mines (MCM); First Quantum Minerals (Canada) which invested in the development of Kansanshi Cu-Au Mine; Equinox Minerals (Canada and Australia), which has developed the Lumwana Mine; and Non-Ferrous China (NFC) Africa (China), which invested in the Chambishi Mine.

Fresh capital investment from these and other sources has increased Zambia's annual copper production, which has risen to above 500,000 tonnes from 2006 for the first time since 1985 (Table 4.3; Fig. 4.4). Main setbacks in the mining sector that negatively affected Zambia's performance include mine accidents, labour disputes, and shortages of fuel and electricity (African Economic Outlook, 2008; World Factbook, 2009). Major challenges to national economic development are unemployment and underemployment as well as the prevalence of HIV/AIDS. Although poverty continues to be significant, as indicated by its low per capita GDP, Zambia's economy has strengthened as shown by real GDP growth in 2005-08 of about 6% per year, single-digit inflation, a relatively stable currency, decreasing interest rates and increasing levels of trade (World Factbook, 2009). However, the recent decline in world commodity prices and demand are expected to result in lower GDP growth in 2009.

5.1.1.3 Democratic Republic of Congo

The DRC, with its large surface area of 2,345,095 km2 and mineral wealth of copper, cobalt, diamond and gold, is potentially one of the richest mining countries in Africa. However, it is still one of the poorest countries in the world, with a per capita annual income of about US$ 300 in 2007 (USAGOV, 2009). In 2007 the DRC had a GDP of US$ 9.85 billion and an annual GDP growth rate of 6.3% (USAGOV, 2009), thanks largely to its natural resources of copper, cobalt, diamonds, gold, zinc, silver, petroleum, wood and hydroelectric potential.

Diamonds, copper and cobalt account for the vast majority of the DRC's exports (US$ 2.350 billion in 2006; SADC Review, 2008) and represent the single largest source for foreign direct investment. The DRC's main copper and cobalt interests are dominated by Gécamines, the State-owned mining giant, whose production has been unfortunately severely affected by corruption, civil unrest, world market trends, and failure to reinvest (SADC Review, 2008). Recently, Gécamines has attempted to improve its declining production by promoting several ailing mines and projects to foreign investors. The renewed interest by the international mining industry in the DRC has been as a result of the 2003 implementation of the new DRC Mining Code, which was drafted in conjunction with the World Bank.

Peace and stability, which are prerequisites for economic development in the DRC, is however still severely hampered by the apparent links between illegal armed groups in the eastern part of the DRC who finance their activities through the exploitation of natural resources (USAGOV, 2009).

5.2 The Colonial Era in Namibia, Zambia and the DRC

During the scramble for Africa, copper deposits became more of a curse than a benefit for the African people due to the exploitative and suppressive nature of colonialism. The word "colonialism" is defined by Webster´s New World Dictionary of the American Language (1957) as "the system by which a country maintains foreign colonies for their economic exploitation".

This definition aptly describes the realities at a time when colonialism was at its peak and well entrenched on the African continent. During colonialism the occurrence of mineral resources was used to determine national boundaries, splitting ethnic groups on either side of the borders. For example, the current border between Zambia and the DRC was determined initially on the 11° parallel from the Angolan border up to the Luapula River. However, the border was subsequently moved to follow the watershed, so that Queen Victoria was able to grant her nephew, Leopold of Belgium, some copper deposits.

During this sad period of colonialism the imperial powers used the copper deposits as a direct resource to develop the economies of their countries in Europe. In contrast, although the indigenous people in the then South-West Africa (Namibia), Northern Rhodesia (Zambia) and Congo Free State/Belgian Congo (DRC) were the legitimate owners of the mineral resources, they had no mineral rights in the colonial territories.

It is worth noting that investments such as railways, roads, ports, airports and buildings, including schools, were for the benefit of the local expatriate workers and colonial aligned companies, such as the British South Africa Company in Zambia (controlled by British and South African interests); the Otavi Minen- und Eisenbahngesellschaft (OMEG) in Namibia (controlled mainly by German and later American (Newmont) and South African (Goldfields of South Africa) interests); whereas in the Congo all copper mining operations were controlled by the Belgian enterprise Union Minière du Haut Katanga.

The benefits that were obtained by the colonial powers from copper mining and the extraction of other resources from the colonies made the struggle for independence from the colonial governments even more difficult. Countries with an abundance of known resources and a good remaining mineral potential were reluctantly given up; whereas those without many known resources were readily given up in the late 1950's to the 1960's.

Copper had become such an important and central metal in the industrial development of nations, as the advent of electronic devices such as washing machines, pressing irons, televisions, stereo sets, new vehicles with ever increasing electrical wiring, and many more electrical and electronic gadgets were produced at a large scale. It was largely the colonial copper production that had made this development possible.

In the 1950s and 1960s it had become obvious that a new decade of invention and progress had dawned upon the World. In this rush to industrialise, copper was central to progress as the known resources were deemed not to be sufficient. The industrialized World had to find a new approached to the issue. The United States of America (USA) initiated a commodity inventory for the entire world, which was then stored in a data base, and developed a policy of importing more raw materials from abroad instead of mining all their own known resources. This was forward planning on the part of the USA, as the country had become the centre of the world's automobile industry, located in the Detroit area of the Great Lakes, close to the iron ore deposits of the Lake Superior region. Alliances were made with South American countries and the DRC to supply the USA with copper and cobalt. At that time Northern Rhodesia supplied mainly the United Kingdom and South Africa; whereas South West-Africa supplied South Africa. It is clear that the mining entities were more aligned to sell the copper to Western countries, and the indigenous people had no say on how the funds thus realized were used.

In order to achieve all this, mining companies needed more electrical power, additional power-lines and generation stations. This resulted in the development of the hydro-electric scheme of the Kariba Dam in 1957-1962. This dam provided the then Northern Rhodesia (Zambia) and Southern Rhodesia (Zimbabwe) with the requisite amount of power for the operating copper, platinum, chromium, nickel and gold mines. Furthermore, the power was required to expand the current operations as from 1956 onwards, and to increase production in the wake of the just ended World War II and the implementation of the Marshall Plan. The Kariba hydroelectric scheme (Fig. 5.1) was later to be inherited by the countries of Zambia and Zimbabwe at their independence in 1964 and 1980 respectively.

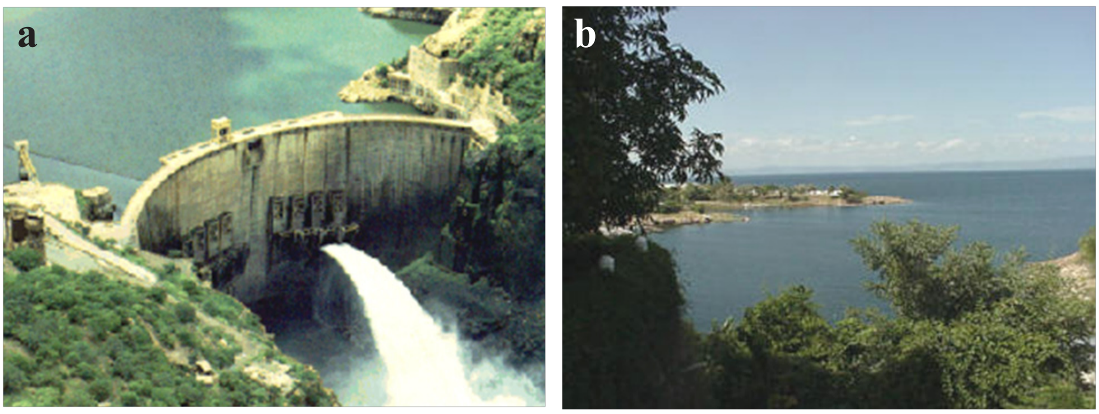


Figure 5.1: (a) Kariba Dam: a benefit that accrued to the newly independent Zambia and Zimbabwe as a result of copper and gold mining, respectively. (b) Lake Kariba, now a tourist and fishing facility as well as a source for hydropower.

5.2.1 South-West Africa

During the colonial era the indigenous people were merely employed on the mines as labourers for low wages under very harsh and poor conditions, as can be observed in Figure 5.2, which depicts some of the living and working conditions under OMEG at the Tsumeb Mine. The low wages that they worked for did not allow them to make any meaningful investments for themselves.

A common colonial practice that was imposed by the mine owners on the African workers was the "single quarters" accommodation system, which was almost universally adopted in the whole of southern Africa, including the gold mines of South Africa and the diamond mines of South-West Africa near Lüderitz. This practice was enforced so that black workers could not live in with their spouses; instead, they had to live as bachelors. Some mining companies like those that operated the diamond fields, strictly controlled the movement of workers to avoid diamond theft. However, in most copper mines personnel were allowed to move in and out of their quarters and mix with other people in their communities.

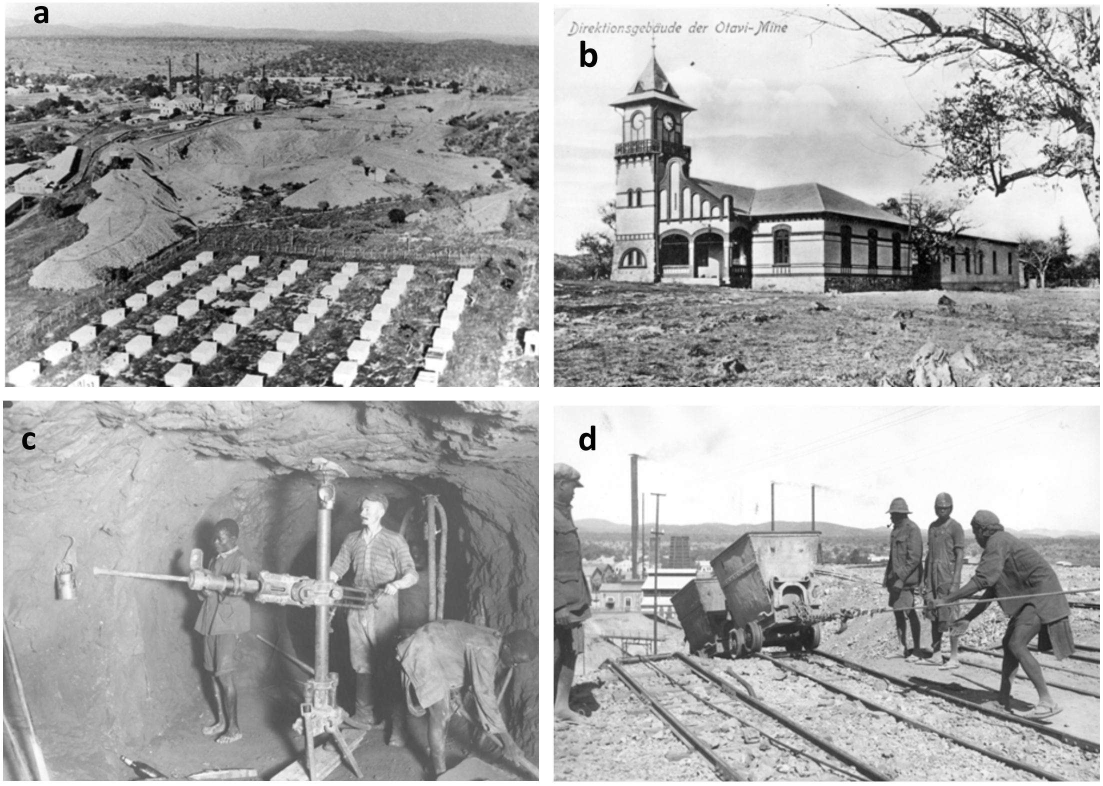


Figure 5.2: Examples of living and working conditions in Tsumeb in 1907. (a) Dormitory housing for African miners at Tsumeb. (b) The early OMEG mining office. (c) An underground drilling crew. (d) Methods of loading ore from the Tsumeb open pit.

5.2.1.1 The Tsumeb example

During the colonial period, mining operations in the region generated substantial amounts of money for their shareholders. Tsumeb is discussed here as a typical example of colonial exploitation of mineral resources.

Francis Galton and C.J. Andersson were the first Europeans to report the occurrence of copper in the Otavi Mountainland of northern Namibia, where the Bushmen and Ovambo people were trading in copper and other goods (Barnes, n.d.; Gebhard, 1999). The South West Africa Company (SWAC) obtained the mining rights from the German government and, in 1892, sent an expedition under Matthew Rodgers to the Otavi

Mountainland, where a number of shafts were sunk at Tsumeb, Guchab, Nageib and Asis (Kombat) (Barnes, n.d.). In 1900, SWAC initiated the formation of the Otavi Minen- und Eisenbahngesellschaft (OMEG), which acquired the mineral rights from the former company.

Between 1903 and 1906 OMEG developed the Tsumeb Mine and built a 566 km long railway line from Swakopmund to Tsumeb. The first smelter plant consisting of two Pb-Cu blast furnaces was built in 1907 (Barnes, n.d.; Schneider & Seeger, 1992). Mine operations between 1907 and 1947 were interrupted by the First World War, the Great Depression and the Second World War. After the latter war, OMEG assets passed into the hands of the "Custodian of Enemy Property" set up by the Allied Forces. A syndicate, mainly consisting of foreign companies, bought out OMEG for the equivalent of 2,020,000 South African Rand and renamed it Tsumeb Corporation Limited (TCL). TCL shipped their first ore in March of 1947.

During the 1950s the Tsumeb concentrates were shipped via the port of Walvis Bay and smelted and refined overseas. However, due to increasing transportation costs, a new smelter was built between 1960 and 1962 (Schneider & Seeger, 1992). The smelter plant produced blister copper (98% purity), lead (99.99% purity) and other products (Arsenic Trioxide (99.0% As_2O_3), Refined Cadmium (99.95% purity), Sodium Antimonate (47.50% Sb)), as well as germanium and gallium. Silver and gold were included in the blister copper, which was refined overseas by means of electrolysis (Schneider & Seeger, 1992; Weatherly, 2008). Mining operations continued at Tsumeb under TCL until 1996 when the mine closed. It was later taken over by Ongopolo Mining and Processing Limited (OMPL), a Namibian company comprising ex-TCL-management and the Workers Union.

Between 1907 and 1996 the Tsumeb Mine produced an average of 351,000 tonnes of ore per annum (tpa) between (Fig. 5.3; Schneider & Seeger, 1992; Kamona & Günzel, 2007) from more than 30 Mt of ore with average grades of 10.4 % Pb, 4.42 % Cu, 3.49% Zn and 125 ppm Ag (Lombaard et al., 1986; Wartha & Genis, 1992; Mines Directorate, 1992-2000). During the period that Tsumeb was in production, it can be argued that there were no direct benefits to the indigenous people of Namibia. The amount of money that both, TCL and OMEG generated from Tsumeb is substantial, and the remaining benefits to the people of Namibia can be seen in the town of Tsumeb. It is, however, clear that more money left the country, compared to what stayed behind. TCL acquired a few corporate farms around Tsumeb, where people were employed. However, once again Africans were mainly engaged as labourers. These farms grew various crops such as maize and vegetables and also kept cattle for both, beef and milk.

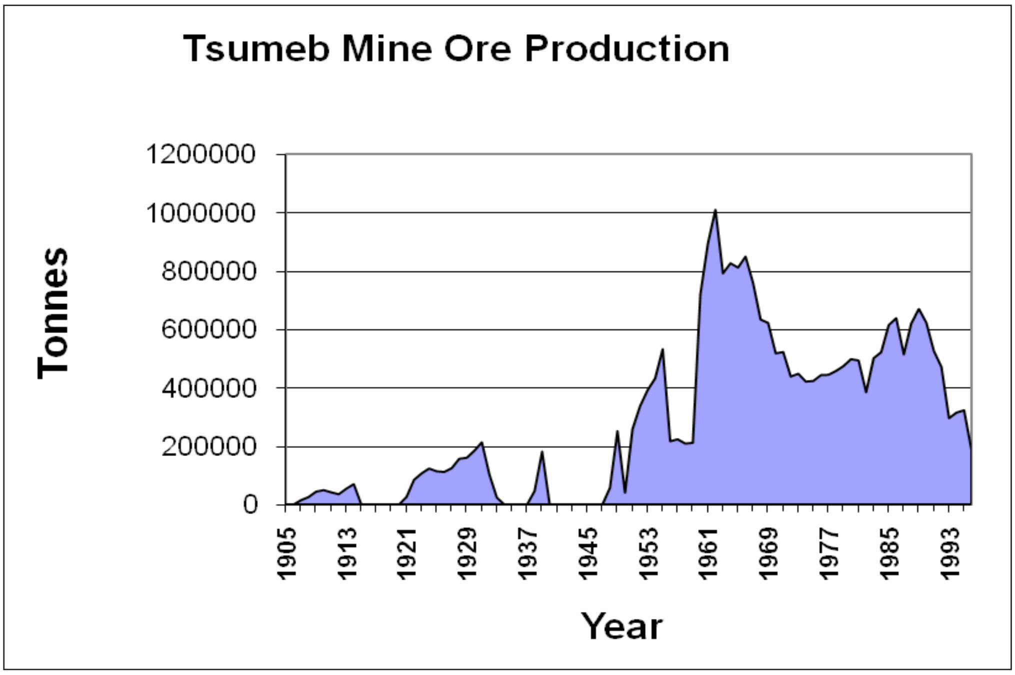


Figure 5.3: Tsumeb Mine ore production between 1907 and 1996 (based on data from Lombaard et al., 1986; Wartha & Genis, 1992; Mines Directorate, 1992-2000).

The other properties owned by OMEG were the Kombat, Abenab, Berg Aukas, Otjihase and Matchless mines. These were also taken over by TCL. Kombat (Fig. 5.4) had an average production of 13,000 tons of copper metal and 5,000 tons of lead metal per year. Except for an interruption during the 1978 flooding, Kombat produced consistently over its life of mine. Otjihase produced about 17,000 tpa of copper concentrate, which was transported to Tsumeb for smelting.

In 1988 the Tsumeb Smelter (Fig. 5.4) reached a record production of over a million tons of metal. At this time TCL's revenue came from various commodities, mainly copper (54.2%), lead (20.3%) and by-product silver (19.6%) with lesser amounts from pyrite which was sold for the production of sulphuric acid, arsenic, by-product gold, cadmium, and sodium antimonate.

Figure 5.4: TCL infrastructural development: (a) the Tsumeb Smelter and (b) an adit at Kombat.

5.2.2 Northern Rhodesia

In the early 1920s, class and national consciousness, as well as political awakening was slowly taking place, particularly through the African labour movements that were created to obtain better conditions of work for the Africans. In Northern Rhodesia the first miners' strike occurred in 1935 in protest against an increase in the "poll tax" by the colonial government without the mining companies raising the miners' wages

(Musole, 1962). According to Musole (1962), after the 1935 strike, in which 6 strikers were shot and killed and 22 others wounded, the miners organised themselves into an African trade union movement which demanded better living, housing and working conditions as well as higher wages for the African miners. In particular, the miners became conscious of being discriminated against by the mining companies who treated them as primitive and ignorant “tribesmen” rather than as workers. As a consequence, the miners went on a “racial strike” in 1940, when they realised that the white employees received preferential treatment and enjoyed better living, housing and working conditions than they themselves (Musole, 1962). In fact, when the white employees went on strike, their demands were met, but the African miners had to sacrifice their lives for their demands to be considered. Thus, a 1940 strike in order to get improved wages and living conditions, resulted in the killing of 17 miners and wounding of 69 others by government forces (Musole, 1962). In line with the colonial spirit of divide and rule, the mine managements also set up “tribal” and “boss-boy” committees to discuss the welfare and employment conditions of the miners, but they refused to recognise the African workers’ trade unions.

5.2.3 The Congo Free Sate and Belgian Congo

Under King Leopold II, who obtained personal title to the territory of the Congo Free State, later to become the Belgian Congo, at the Berlin Conference in 1885, mine workers experienced a worse fate than their counterparts in Zambia (Information-Please, 2008). The brutal colonial rule of Leopold resulted in the death of more than 10 million people from forced labour, starvation and extermination. The country remained a colony until June 30, 1960, when Independence was obtained.

The Congo has found little peace ever since the assassination of Comrade Patrice Lumumba, the first legally elected Prime Minister of the independent Republic of Congo, by a Belgian mercenary, after the mineral rich Katanga Province seceded from the new Republic in 1960 (InformationPlease, 2008).

5.3 Developments After Independence

5.3.1 Namibia: benefits from large scale mining

In the course of the 20th century, urbanization began to take shape in all copper mining towns of southern Africa as a result of mining operations. In South West Africa, the town of Tsumeb grew and became a magnet for other industries that supported the Tsumeb Mine and its satellite mines of Abenab, Berg Aukas and Kombat since the days of OMEG. Tsumeb continued to be a hive of activity for the newly independent Namibia under TCL between 1990 and 1996, and it is one of the few mining towns that have continued to exist even after mine production ceased in 1996. The continuation of economic activities in the Tsumeb area may be attributed to the leadership of the South-West African Peoples Organisation (SWAPO) government which took over power in 1990.

At independence, SWAPO, unlike most liberation movements, was ready to take over the reins of power, since it had educated and trained principal cadres who were prepared to lead and formulate development plans that would guide the new nation. The education and training of Namibians during the freedom struggle was made possible through the support of various countries and organisations, including institutions such as the United Nations Institute for Namibia, which was based in Lusaka.

When TCL closed the Tsumeb, Kombat and Otjihase mines in 1999, the Namibian Government empowered the Worker's Unions by giving them guarantees and loans to continue the mines under the new name of "Ongopolo Mining and Processing Limited" (OMPL). This move ensured the continuation of mining operations that benefitted the people of Namibia directly, since there were no longer cash outflows due to the externalisation of profits from Namibia. The management and workforce of OMPL were by and large Namibian, with Namibian interests, albeit with a few expatriates remaining in specialized functions of engineering and geology. However, on the whole the aims and objectives of the copper mining industry had Namibian interests in the forefront and the country benefitted from the copper revenues in contrast to the colonial period when foreign interests prevailed.

OMPL was disadvantaged from the beginning by not having well trained professionals in the industry, a legacy from the TCL days. The lack of local expertise hampered the management of the new organization; increasing inefficiencies and reducing productivity. OMPL did not invest heavily in education and did not focus on its future role, so as to position the organisation for the changing world economic climate. However, the fact remains that from 1999 to 2005, OMPL was wholly Namibian-owned and the country benefitted the most for the first time in that short period since 1850.

OMPL could not sustain its operations for long, largely as a result of poor management decisions and investments which would have led to liquidation. The company was bought out by Weatherly International in 2006, when a new era once again opened up for the Namibian copper industry. From 2006 onwards, the Namibian copper industry has once again been in the hands of an international company, the principal interest of which has been to operate the Tsumeb smelter rather than to take over the heavily indebted mining operations.

By November 2008, all the mining operations of Weatherly International in Namibia were closed, with the exception of the Tsumeb smelter, apparently due to the sudden decrease in world metal prices, as copper had fallen from a high of US$ 8,000 to US$ 3,400 per tonne. The sudden closure of the Weatherly mines reflects the manner and interest of international companies, whose main aim is primarily profit, regardless of the socio-economic climate of the country they operate in. The mine closures have put a severe strain on the Namibian economy, as there is now no copper production and close to 600 employees lost their jobs within a month. It is difficult to predict whether all these copper mining operations (Otjihase, Matchless, Kombat, Tschudi and Tsumeb West) would have been closed, if OMPL was still running them. Probably a compromise solution would have been reached to continue some of the operations for a while. From the mineral economics point of view, a price of US$ 3,400 per tonne is marginally sustainable, as long as the oil price remains below US$ 50 per barrel. At the time of the closure, oil prices had fallen to about US$ 45 per barrel.

The positive impact made by the copper mining industry to Namibia's economy, along with those from other mining operations based on diamonds, zinc, lead, uranium, gold and fluorspar, has been reversed due to the mine closures and layoffs resulting from the fall in world metal prices. Apart from unemployment and reduced government revenues, some mining settlements, such as Kombat, face the possibility of becoming ghost towns. However, Tsumeb will continue to exist due to the well established farming activities in the surrounding region and the Tsumeb smelter operations.

5.3.1.1 Benefits to the local mining towns in Namibia

The towns of Tsumeb, Kombat and Grootfontein are well serviced with an excellent transport infrastructure. This in general raises the standard of living of the people. The businesses that initially largely serviced the mining operations in these towns have now been transformed to serve communities with varied business interests, ranging from tourism and agriculture to smelting. Other new businesses, such as for example aquaculture, have also developed. In particular the town of Tsumeb has managed to survive the closure of its largest mine, and has evolved into a centre for artisanal and mechanical businesses.

Apart from the Tsumeb smelter, downstream industries that add value to copper mining are absent in Namibia. The Tsumeb smelter upgrades the copper concentrate to only about 98% metal in blister copper (Fig. 5.5), with precious metals of gold and silver still present in the final product and requiring electrolytic refining for recovery elsewhere.

Figure 5.5: (a) Blister copper produced at the Tsumeb smelter. (b) Size of blister copper in comparison to humans.

The country has now embarked upon a programme to develop small to medium enterprises (SMEs), a project under the auspices of the Office of the Prime Minister. Export Processing Zones (EPZ) introduced in 1995, have started to attract some investments, albeit in small amounts. However, in the mining sector they have proved to be counterproductive, as the copper smelter and the zinc refinery of Skorpion Zinc, both having EPZ status, do not pay taxes and their mining products therefore leave the country without contributing to tax revenues. A rigorous royalty scheme was therefore introduced by the Minister of Mines and Energy in 2006.

It is imperative for government to take a leading role in the development of manufacturing industries allied to mining, such as the diamond cutting and polishing centre in Okahandja which was introduced in 1998. Such initiatives should be expanded to include base metals (zinc, lead, copper), industrial minerals and other Namibian commodities. But at the same time, it should be noted that another setback of the EPZ scheme, when applied to the mining industry, is the represented by the diamond sector. Uncut diamonds attract a 10% royalty, whereas cut stones can be exported without royalty. The granting of EPZ status to diamond cutting factories, in an effort to attract investment, has led to a situation, where such companies pay neither royalty nor tax, the only benefit accruing to the country being the jobs generated. Government must therefore carefully consider which incentives it can offer for a meaningful stimulation of the value adding sector.

5.3.1.2 Benefits from small scale mining in Namibia

Small scale mining in Namibia has mostly been restricted to cassiterite (tin), tantalite (niobium-tantalum), semi-precious stones and mineral specimens. During the days of Ongopolo, small scale miners were encouraged to supply ore to the Kombat concentrator. However, this idea never took off due to lack of financing for the small scale miners who were had organised themselves to mine the small copper occurrences in the Otjiwarongo and Oamites areas. With the closure of the mining operations in November 2008, this option is even more difficult to resuscitate. Small scale miners could be paid on the basis of tonnage of processed ore and final metal output from the smelter. Such steps would ensure that small ore bodies that may not be of interest to large firms can be mined economically and at very little cost to the big companies, with substantial benefits to the small scale miners.

5.3.2 Zambia: Benefits from large scale mining

The construction of the 128 meter high Kariba Dam (Fig. 5.1) was a direct result of the mining industry on the Copperbelt which consumed 60% of the power generated for Northern Rhodesia at the time. The construction of the dam can be linked directly with the need for energy in the copper industry, and not because the colonial government (at that time the Federation Government of Rhodesia (North and South) and Nyasaland

(Malawi)) wanted to develop the region. Nevertheless, the supply of electricity from Kariba Dam has helped to improve the standard of living for people in both Zambia and Zimbabwe. Since its commissioning in 1963, Kariba Dam has been further upgraded to include four new generators on the north bank, in addition to the original four generators on the south bank.

Although hydroelectric dams such as Kariba are major infrastructural developments that supply electricity and provide a stimulus for development of other industries (e.g. tourism and fishing), there are also some negative consequences, including earthquakes and tremors caused by the filling of the reservoir, flooding of the land and the resettlement of wildlife and local inhabitants in the region. The construction of Kariba Dam, which began in 1956, resulted in the disruption of the life and culture of the local people. “Operation Noah”, an animal rescue operation that was put in place by the Colonial Government, only ensured the safety of wild animals, but did not take into account the resettlement of the local population. The Gwembe Tonga were forcibly removed from the area and, even worse, they had to find alternative settlement areas on their own, since no such areas were designated for them. Most indigenous people ended up losing their domestic animals (cattle, goats, and sheep) and other personal property, because they were neither informed nor counselled beforehand about the project and its impact on the local communities. As far as the Federal Government of Rhodesia and Nyasaland was concerned, the locals were just “Africans” with no “property” rights and hence of no importance. The animals enjoyed better welfare in the world of 1957 - all in the name of providing electricity for the copper mines. No funds were provided for the resettlement of the 57,000 Tonga-speaking people who were affected by the dam construction, although, according to Scudder (2005), the copper industry had been prepared to fund ‘before and after’ resettlement studies.

Compensation for the Gwembe Tonga was only possible after independence in the form of "accelerated" development provided by the Zambian government under the leadership of His Excellency Dr Kenneth Kaunda. In 1968/69 the Zambian Government introduced the sardine-like "kapenta fish" (Limnothrissa miodon) from Lake Tanganyika into Lake Kariba, and by the late 1980s, the annual catch totalled about 30,000 tonnes which has, however, declined since the 1990s (Magadza, 2006). The Lake Kariba fishery was therefore developed as a result of mining activities and it has now benefitted both, the local population on either side of the lake, and new players like large fishing companies, who have commercialized the industry.

Another historic development in the decolonization of Zambia under Comrade Kaunda was the construction of a national university solely from funds donated by the Zambians in 1966. This national project was necessitated by the need to train and educate Zambian professionals to run the national economy and mining industry, since at independence there were only about 500 graduates in the country. During the colonial days, Africans were not allowed to hold positions as engineers, geologists, surveyors, metallurgists and mining engineers in the mining industry, because such jobs were reserved for members of the white community who were brought in mainly from South Africa and Britain. It was hence imperative for the Zambian government to train its own personnel to run the copper mines.

By 1968, the government had come to a conclusion that "a fair share of the copper mines" should be in government control. But negotiations with the parent company, the Anglo-American Corporation of South Africa, did not proceed well. This led to the unilateral takeover of 51% of the shares in all the copper mines, with Anglo-American owning about 36% of the shares and other investors some 13%. This state of affairs appeared well and good on the surface, but the negotiated settlement was not fair to the Zambian government. During negotiations, the government agreed to cover all pro-

duction costs, despite the fact that they only owned a 51% stake in the enterprise. This state of affairs was arrived at due to the non-availability of trained mineral economists and lawyers acquainted with international trade on the side of the Zambian government. Thus ZCCM (Zambia Consolidated Copper mines) was born by the merging of the Nchanga Consolidated Copper mines (NCCM) and Roan Copper Mines (RCM). In addition to the taxes from the mines, which were being obtained in the pre-1968 period, the government now also received 51% of the dividends.
As a result, in the 1970s, using these funds, the government of President Kaunda embarked on a programme of building secondary schools with boarding facilities in all 53 districts. This was followed by the building of district hospitals. At that time the government did not have sufficient manpower to operate this new infrastructure, and manpower was thus imported in the form of expatriates. It is worth mentioning that at independence, most schools were run by missionaries, and there were few government schools that were run by the colonial government. These existed only in large towns with a large expatriate community such as on the mines, in Lusaka, Livingstone and Kabwe.

The formation of ZCCM was instrumental to the development of local expertise. The new parastatal served as a major arm in the training of Zambians. ZCCM sponsored a wide variety of students, across all disciplines, further more they afforded all tertiary institutions with vacation training facilities. This cemented the link between colleges, vocational training centres and universities as far as practical training was concerned. It meant that by the time engineers, chemists, geologists, economists, social workers, carpenters, boiler makers, technologists, doctors, nurses and many more other professions had completed their studies, they had a good idea of the practical side of what the work they were going to do involved. ZCCM also built its own hospitals, schools, and invested in farms and other industries. These programmes helped in establishing a group of well experienced Zambians, who not only worked in the copper industry, but other industries as well. ZCCM also instituted its scholarship programme, apart from the Zambian Government's own scheme. This scheme identified students who performed well at grade 12, and these were subsequently sponsored to undergo tertiary education in fields in which ZCCM was still understaffed, including management and technical professions.

Probably one of the best benefits that Zambia obtained from the copper industry was the education and training of its citizens. The downstream industry that stemmed from the establishment of ZAMEFA was an excellent initiative, as Zambia could now process some of its copper into finished copper wire, rods and conductors (Prof. Imasiku Nyambe, 2007, pers. comm.). It is regrettable that no other new developments, such as the manufacturing of electrical goods for example, took place in the country until the late 1990s. Today a small sector produces appliances such as pressing irons, but more could be done with a strategic partnership of Government-private sector investment initiatives.

In the education sector the copper industry assisted the Ministry of Education to provide bursaries thorough a "Bursaries Committee" specifically created for Zambian students to access tertiary education. The Zambian government also paid school fees for both primary and secondary schools, and tuition fees for students who got admission to tertiary institutions. This policy helped to train civil servants in all fields such as engineers, geologists, doctors, nurses, economists, psychologists, social workers, dieticians, agriculturalists, veterinarians, biologists and microbiologists, to mention but a few, many of whom continued to work for the private sector.

This policy has now been modified under the MMD government, which offers education and training via a cost sharing policy. Students, who perform very well, get a 75% subsidy for their tuition fees at universities and other tertiary institutions. However, free education at primary schools and secondary schools has all but come to an end. As a consequence Zambia is lagging behind other SADC countries in terms of student enrolments to primary, secondary and tertiary institutions (Table 5.2). Other industries that have developed and grown, such as agriculture, manufacturing and the financial sector, do not have the same impact as copper mining had in the 1970s and 1980s in Zambia.

Table 5.2: SADC Education average enrolment indicators for 1998-2000 (Winter, 2008)

Country	**Population**	**Primary School enrolments**	**Secondary School enrolments**	**Tertiary Institutions enrolments**
Angola	11200000	50	25	1
Botswana	1448000	108	65	6
DRC	60000000	72	26	2
Lesotho	2090000	108	31	2
Malawi	1090000	89	17	1
Mauritius	1168000	107	65	7
Mozambique	18614000	60	7	1
Namibia	2000000	131	61	9
Seychelles	79000	no data		
South Africa	44000000	131	94	19
Swaziland	1000000	15	9	1
Tanzania	32000000	66	5	1
Swaziland	1000000	15	9	1
Zambia	10000000	89	27	3
Zimbabwe	12000000	113	49	7

At the time of independence, the population in Zambia amounted to about 6 million people, but it has now increased to 11.7 million. As a consequence, more institutions of higher learning are required, over and above the two that have been servicing the country. In addition, students from poor families, who qualify for tertiary education, but have no funds, will no longer be able to obtain a college education and the number of graduates from colleges and universities will continue to decrease as shown in Table 5.2.

After 1991, the Copper mines were again privatized by the MMD government. This new phase in the Zambian copper mining industry saw new and old players on the scene. Initially, the Anglo-American Corporation of South Africa bought some of the properties at Nchanga and at Nkana, but later sold these properties citing low metal prices. However, the current owners of Nkana and Mindola mines in Kitwe (Mopani Copper Mines) have re-capitalised and mining has continued at a steady pace. New entrants to the mining industry include Nchanga mines and KCM (Konkola Copper Mines). Of the new entrants, KCM has perhaps made the largest investments in the mining sector. A new shaft (Fig. 5.6) to access the ore bodies at deeper levels (up to 2 km) has been installed and will be commissioned in 2009. New mines have also opened in the North-western province of Zambia, an area which traditionally has not been known as part of the Copperbelt (except in geological concepts). The Kansanshi Cu-Au Mine has been re-opened by First Quantum Metals, whereas construction at the Lumwana Copper Mine of Equinox Minerals started in 2006 with about 4,700 local workers and full production will be reached in 2009 (Equinox Minerals, 2008). These new developments will in turn initiate some economic activity in this part of the country.

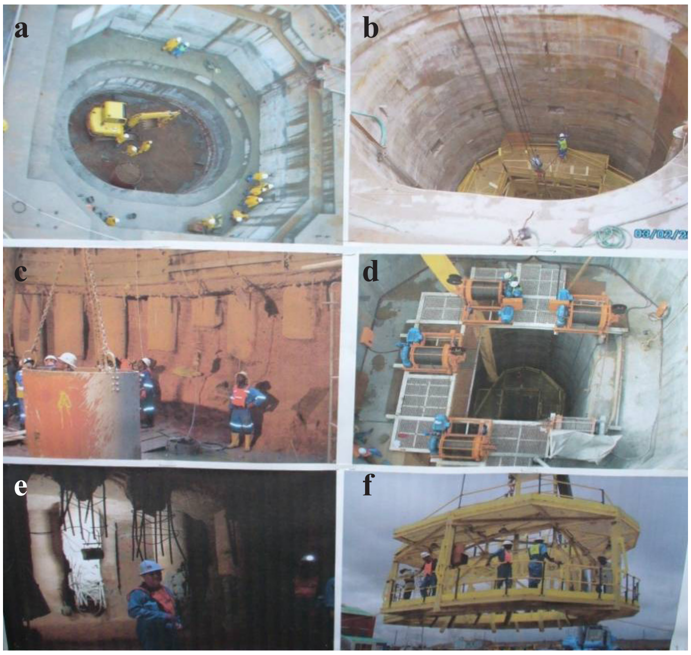


Figure 5.6: Stages in the building of a deep shaft at Konkola Copper Mine (KCM) in 2007: (a) Shaft development in the early stages, (b) lining of the shaft, (c) installation of equipment, (d) shaft lining in progress, (e) installation of reinforced concrete pillars in the shaft, and (f) the crane used by the construction crews.

Manufacturing in Zambia is much larger than in both the DRC and Namibia. Zambia is highly industrialized and industry accounts for over 60% of the work force in (The State of the Environment in the Zambesi Basin, SADC, 2000). However, Zambia's large base of indigenous manufacturing industry is mainly non-mining. The largest companies are Chilanga Cement, which directly supports the mining sector, Lever Brothers in the cosmetic and detergent sector, Nitrogen Chemicals mainly in fertilizers and lime; Zambia Breweries, Zambia Sugar, Indeni Refinery (crude oil refining process) and ZAMEFA. Of the large manufacturing companies, only ZAMEFA is a direct downstream industry and the others are largely suppliers to the mining industry. This state of affairs suggests that manufacturing as a result of mining is still in its infancy. Unless this changes, and it can only change if large investments driven by government policies are put in place, the SADC region will forever export raw materials to the technologically advanced countries.

5.3.2.1 Benefits to the local mining towns in Zambia

On the Zambian Copperbelt, a number of towns developed as a result of mines that opened in the area, including well known towns such as Chililabombwe (Konkola Mine); Mufulira (Mufulira Mine); Kitwe (Mindola and Nkana Mines); Luanshya (Baluba Mine); Ndola (Bwana Mkubwa Mine); Kalulushi (Kalulushi Mine); Chingola (Nchanga Mine); Chambishi (Chambishi and Chibulama mines). All these towns evolved around the mining activities, and only some towns like Kitwe and Ndola, for example, have had extra investments in other sectors of the economy such as manufacturing, transport, trade and education (the Copperbelt University and the Zambia Institute of Technology). Consequently, the towns of Kitwe and Ndola are expected to survive and continue existing as commercial centres even after the mines close.

However, other towns, especially Luanshya and Kalulushi and, to a lesser extent, Mufulira, have been struggling since the down turn of the early 1980s. Most of the inhabitants have moved on to different towns, where they can sustain themselves. Most retail shops have also re-located to other towns where the market is bigger (e.g. Kitwe, Ndola). Recently, Kalulushi has seen the re-emergence of the timber industry, a legacy of one of the programmes of the Kaunda era - planting trees for the wood processing industry. A new company has taken over the ZCCM analytical services that were based in Kalulushi, but the success of this private enterprise depends on the growth of the mining industry and its ability to diversify its analytical services to other sectors such as agriculture, water and forensic studies. Luanshya continues to suffer from mine closures and new industries or services need to be introduced to revitalize the town and prevent further economic stagnation.

5.3.2.2 Benefits from small scale mining in Zambia

Small scale mining in the base metal sector has not been popular in Zambia. Only in a few instances have small scale miners been encouraged to supply ore to a smelter. The reasons have been varied, from small tonnages being brought at different grades that do not necessarily fit the "mill grade" for a particular concentrator, to difficulties in paying such small scale miners. It has not been customary for small scale miners to build their own concentrators and smelters as that would have been far too expensive for them. Furthermore, they would need to obtain licenses to erect such facilities and the necessary legislation needed to be in place. As a result, the small scale miners in Zambia have mainly depended on the eagerness of geologists and metallurgists to involve them in mining activities. This practice occurred at Kabwe from 1987 to 1990, when small satellite Zn-Pb prospects in the area were mined and the ore was sold to the mine by small scale miners. The small scale miners were only required to sort the ore in accordance with the mine grading system, before it could be sent to the mill.

5.3.3 Democratic Republic of Congo: benefits from large scale mining

It was no surprise that the newly independent governments' position on copper mining in Congo (DRC) and Zambia was veered towards policies that would benefit the indigenous peoples. After the election of Comrade Patrice Lumumba as first Prime Minister in an independent Republic of Congo in 1960, he made it clear that the wealth of Katanga (referring to the copper mines in the Katanga Province, Figure 5.7) would be distributed fairly to all the citizens of the Congo. However, within weeks of independence, the Katanga Province seceded from the new Republic and Lumumba was soon killed in an assassination organised by Moise Tshombe, the then President of Katanga, and in which U.S. and Belgium involvement has been alleged (Information-Please, 2008).

War soon broke out in the Republic of Congo, when leftist revolutionaries rebelled against the government of the first President Joseph Kasa-Vubu, but the revolutionaries were eventually defeated by foreign mercenaries and Belgian paratroops airlifted by U.S. planes. In 1963, General Mobutu Seseseko, the army chief of staff, overthrew Kasa-Vubu in an armed coup and nationalized the Belgian copper mining enterprise, Union Minière du Haut.

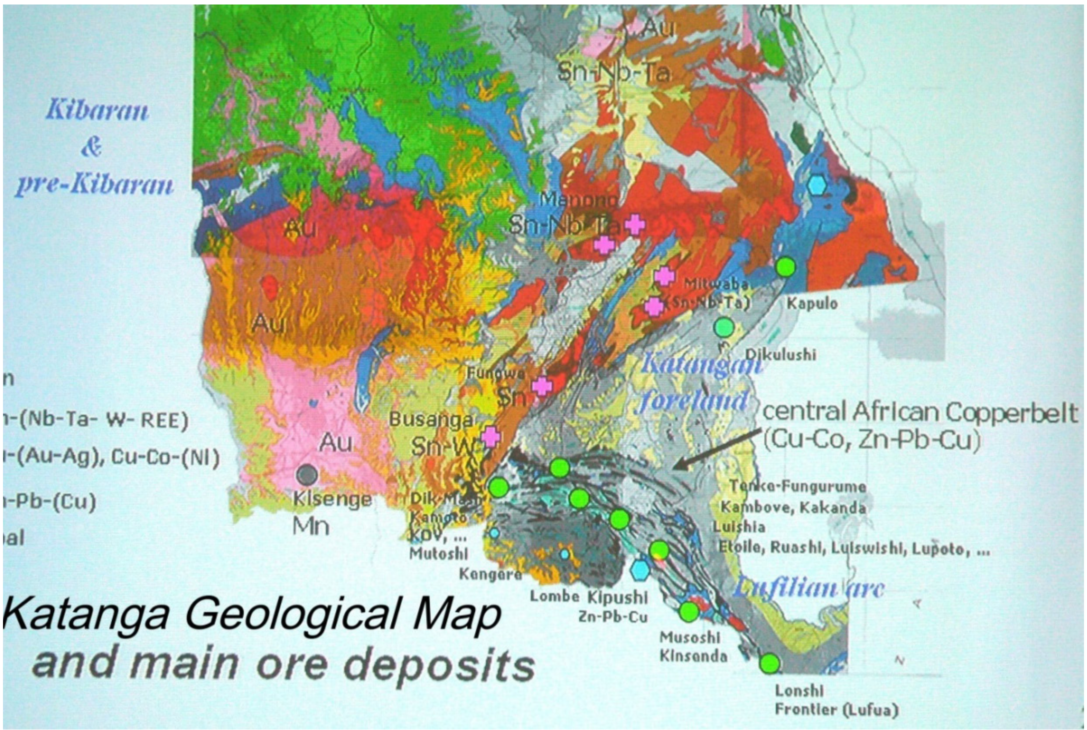


Figure 5.7: Geology of the Katanga Province, showing the location of the main copper deposits in green (after M. Forest Group, Lubumbashi).

During President Mobutu's despotic regime from 1963 to 1997, Congo's mineral wealth continued to be exploited unabated by the Belgians, with little benefit to the general population, while Mobutu also siphoned off millions of dollars. Under Mobutu, the mines were operated by Gècamines, a parastatal enterprise with Belgian companies as shareholders. Profits were not reinvested into the mines or exploration, nor into the local communities, with the exception of the local infrastructure, which was however, only maintained to benefit the mines. No meaningful amounts of money whatsoever were invested in the country's general economic development, resulting in a slow but steady decay of the mining infrastructure (Fig. 5.8).

Eventually, Mobutu was overthrown by Comrade Laurent Kabila in May 1997, despite the military support he had long enjoyed from Belgium, France and the U.S.A.

Figure 5.8: Two views of a dilapidated Gècamines flotation plant in Lubumbashi due to lack of reinvestment.

Between 2003 and 2005, the Malta Forrest Group took over some of the Gécamines mines, such as those at Likasi (Fig. 5.9), and recapitalized and refurbished them so that the industry began to function again. In addition, the local communities in the vicinity of the mines have benefitted from the new schools opened by the Malta Forrest Group. The students at these schools do not pay any fees and this show of social responsibility has gained the mining company the favour of the population. One of the schools is shown in Figure 5.10, on the occasion when the author met with the teachers and students. The school is run very professionally and this is a direct benefit to the country from the mining of its copper resources. If adopted by other mining companies, for social investments such as schools and hospitals.

Figure 5.9: (a) The Likasi open pit, owned by the private enterprise, Malta Forrest Group and (b) the processing plant in Lubumbashi.

Figure 5. 10: (a) The author at a meeting with High School students, 50 km south of Lubumbashi. The author standing next to George Forrest (3rd from left, front row, dressed in a green shirt), owner of the Malta Forrest Group of companies.

5.3.3.1 Benefits to the mining towns in the DRC

The Katanga copper mining activities have had much more traumatic experiences than most other areas. This is largely due to the organization of the country, with the Katanga Province being one of the principal income generators for the DRC. As such, the share of the wealth from Katanga has long been a bone of contention to the central government in Kinshasa, as Katanga has always provided more money per capita than the other provinces. Nevertheless, the Katanga Province still has abundant reserves of copper remaining, and has a much brighter future if the revenue obtained from the mining of these reserves were put to good use.

Notable copper mines are at Kolwezi, Likasi, Kipushi, Musoshi, Lonshi, Dikulushi, Lombe, Ruashi, Kongera, Mutoshi, and Luswishi. Most of these mines have average grades of 3-4% Cu, which are much higher than those in Zambian mines (1-2% Cu). During this study, a visit was paid to Kolwezi, Luiswishi, Likasi and Lubumbashi, the capital of Katanga Province.

Lubumbashi as the capital of Katanga has benefitted the most from mining, since regulatory functions are based in this town, and mining companies have to do business with government in Lubumbashi. The new processing plant owned by Malta Forrest and Société Pour le Traitement du Terril de Lubumbashi (STL) uses new technology to extract precious metals associated with zinc, cobalt and copper (Fig. 5.11). The STL plant processes slags from previous mining activities and represents a substantial development in Lubumbashi, employing close to about 400 workers.

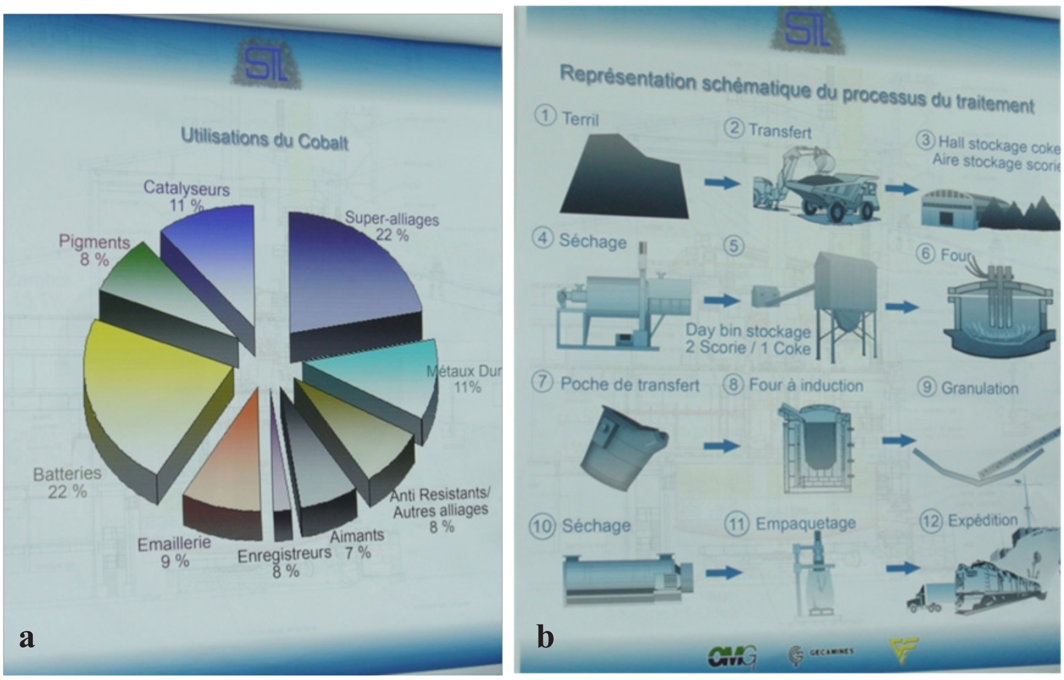


Figure 5.11: (a) The Lubumbashi STL plant flow diagram of the handling and processing of slag material and (b) pie chart showing some uses of finished cobalt.

Copper mining has returned to Kolwezi (Fig. 5.12a), but it will take some time to increase productivity to the high levels of the 1970s. Most of the former houses, where the mine workers used to stay, are now empty, and some sections of the city look like a ghost town. The reason for this state of affairs is the previously mentioned lack of deliberate policies to help the town to outlive the copper mining boom. As soon as mining came to an end, everything else stopped as well. Businesses moved out and the social infrastructure such as community services ended. At Kolwezi one can directly witness the problems associated with mining towns after mine closure. The town has an extensive network of processing plants which, need much investment to return them to the excellent state they were in previously. Kolwezi therefore shows why it is important to maintain equipment and plants as mining is progressing, and to re-invest in other sectors of the economy (e.g. agriculture, manufacturing, transport, education and trade) which may continue to function once mining has ceased. Nevertheless, there are signs that new investors may come back to Kolwezi and resuscitate its past glory.

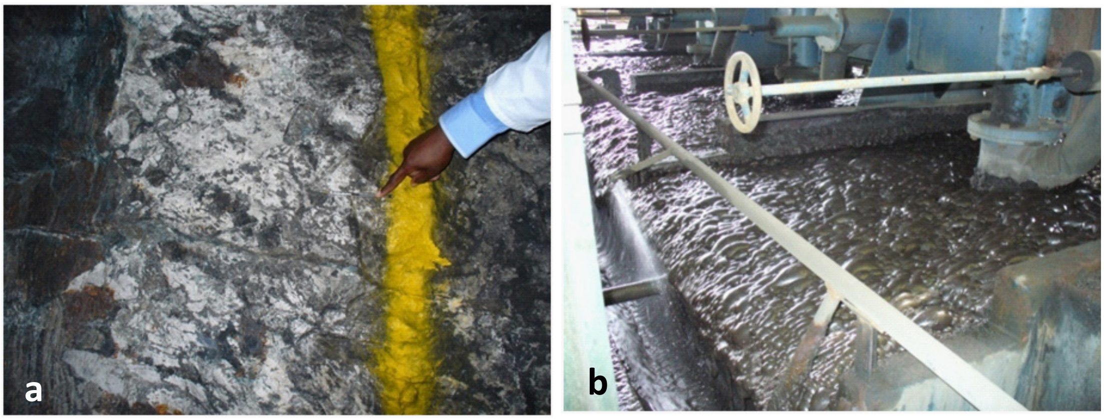


Figure 5.12: (a) High grade sulphide ore at Kolwezi underground mine with malachite and azurite staining. (b) Sulphide flotation plant for separation of copper from the ore at the Likasi plant.

The situation is much more dire in Luswishi. Apart from the metallurgical plants, which are in a much worse state than the ones in Kolwezi, the large scale mining operations are virtually at a standstill. Instead, small scale miners (Fig. 5.13) are now mining ore and sell it to Indian and Chinese small scale buyers in 50 kg bags. The latter smelt the ore in small backyard furnaces for export to China.

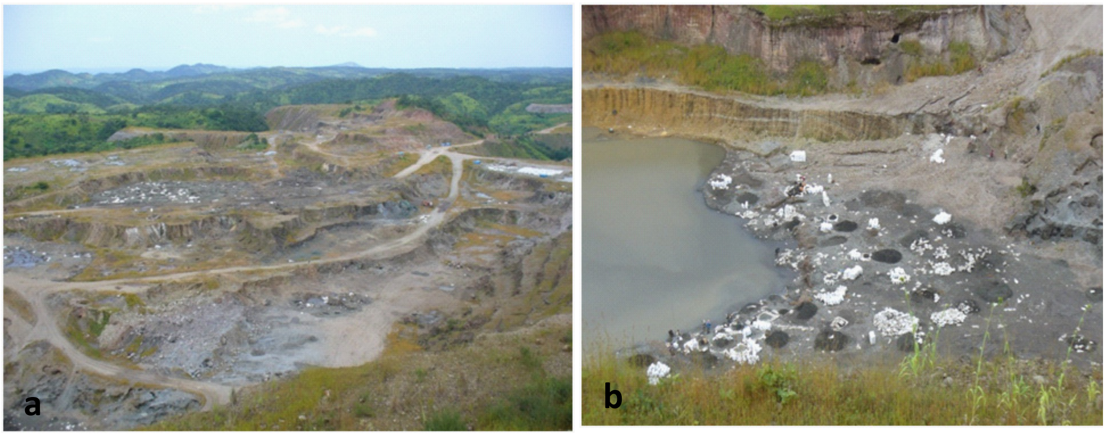


Figure 5.13: (a) Landscape created by small scale mining in Likasi. (b) White 50kg bags loaded with oxide ore, ready to be sold.

5.3.3.2 Benefits from small scale mining in the DRC

Small scale mining became a major source of ore in the DRC in the early 1980s, when re-capitalisation of the mines became problematic. Small scale miners started to mine small ore deposits, especially oxide and carbonate deposits, and sold the ore in bags to the big mining companies.

However, it is unfortunate that the small scale miners always lost out when bargaining for the prices of their ores. As their product had been handpicked, some of it did not meet the requirements of Gècamines, in which case a geologist would value it. Payment was then made based on the value determined by the Gècamines official.

This arrangement is still in practice today, and the government has not yet regulated the industry. Since 2004, small scale Chinese and Indian operators have become involved in the DRC small scale mining sector. The fact that the Chinese small scale miners smelt their ore in backyard furnaces is a source of concern, since the general health and factory regulations are not enforced, leading to poor health conditions of the labourers employed by these foreign entrepreneurs.

5.4 Environmental Considerations

A detailed analysis of the environmental impact of mining operations in mining districts is beyond the scope of this thesis. However, brief mention must be made of the importance of sustainable development with regard to mining operations, since best practices will have to be adhered to in order to safeguard the environment. Relevant best practices which take into account the local community and the environment must be implemented in accordance with suitable codes of conduct, such as those of Albidon (2007) and the International Institute for Sustainable Development (IISD) of Canada (IISD, 2002).

According to IISD (2002), the following seven questions must be considered in order to assess the sustainability of mining projects:

1. Engagement. Are engagement processes in place and working effectively?
2. People. Will people's well-being be maintained or improved?
3. Environment. Is the integrity of the environment assured over the long term?
4. Economy. Is the economic viability of the project or operation assured, and will the economy of the community and beyond be better off as a result?
5. Traditional and non-market activities. Are traditional and non-market activities in the community and surrounding area accounted for in a way that is acceptable to the local community.
6. Institutional arrangements and governance. Are rules, incentives, programmes and capacities in place to address project or operational consequences?
7. Synthesis and continuous learning. Does a full synthesis show that the net result will be positive or negative in the long term and will there be periodic re-assessments?

In this regard it is gratifying to note that one of SADC's many objectives is to (SADC Review, 2008): "Achieve sustainable utilisation of natural resources and effective protection of the environment." It is therefore hoped that the SADC member states harmonise their mineral and mining policies in line with the above best practices for the benefit of future generations.

CHAPTER 6: DISCUSSION

6.1 Pre-colonial Mining in Southern and Central Africa

According to Miller and van der Merwe (1994), the migration of Bantu-speaking people into southern Africa in the late first millennium B.C. brought an agricultural iron- and copper producing society to the subcontinent. The widespread pre-colonial copper mining that took place in southern and central Africa is indicated by archaeological artefacts found in the Rehoboth, Onganja-Matchless and Tsumeb mining districts of Namibia (Hälbich, 1968; Lau, 1987; Sandelowsky & Pendelton, 1969; Schneider & Seeger, 1992; Miller et al., 2005), the ancient mining sites at Bwana Mkubwa and Kansanshi in Zambia (Gunning, 1961) and Etoile du Congo in the DRC (Angermeier et al., 1974). Copper mining and smelting took place for over a period of more than 500 years as indicated by the smelting sites in Namibia which have been radiocarbon dated to between the 15th and 19th centuries (Kinahan & Vogel, 1982).

The ancient copper production technology used by the Bantu may have initially evolved directly from native copper metal, which is very common at the ancient mining site of Onganja in Namibia. According to Cairncross and Moir (1996), large native copper specimens weighing up to 400 kg have been recovered from Onganja, where the copper deposits also contain cuprite, malachite, azurite and chalcocite. The copper oxides provided the raw material for the ancient copper smelting activities that developed in Namibia, Zambia and the DRC, and from which tools, weapons and jewellery were produced for local and inter-regional trade. The unique stone-based smelting technology discovered in central Namibia, which used stone rather than the usual clay technology for furnaces and tuyères points to local innovation or adaptation and also shows that clay ceramic technology is not a necessary precursor to metals production

(Miller & Sandelowsky, 1999; Miller et al., 2005). However, there is insufficient evidence to determine whether or not the stone-based smelting technology preceded the clay ceramic technology for copper production in southern and central Africa.

No proper records of the pre-colonial copper production exist in terms of tonnages produced, but the trade in copper in exchange for other goods such as salt, cloth, tobacco, livestock and beads was quite extensive in the interior and along the western and eastern coastal areas of the southern African sub-continent (Sharpe, 1968; AdeAjayi & Crowder, 1985; Miller & van der Merwe, 1994). This traditional mining and trade in copper by indigenous Africans was disrupted by the arrival of the European explorers, who claimed the copper deposits on behalf of the colonial masters and their mining companies (Nujoma, 2001), and who commercialized copper production early in the 20th century, between 1900 and 1930. As a result, the ancient smelting technology is all but lost, and blacksmiths engaged in copper smelting in Namibia, Zambia and the DRC are virtually non-existent at present.

The author concurs with Miller (1995), who has suggested that the study of archaeometallurgy should be introduced in undergraduate geology and engineering courses to address the current poor state of knowledge about the early history of indigenous mining and metallurgy in southern and central Africa. Ancient indigenous mining and metallurgy is an integral part of African history and culture, and it should therefore not be neglected or forgotten.

6.2 Copper Production in Namibia, Zambia and the DRC

6.2.1 Namibia

Exploration of the Namibian coast began in the late 1400s by Portuguese, Dutch and English explorers, who were searching for a sea route to India. By the early and mid-1800s, missionaries and traders settled inland, after they were given the land by the local Chiefs. The missionaries and traders were soon followed by military reinforcements, who claimed territories of material or strategic value for themselves, including the ports of Walvis Bay and Angra Pequena (Lüderitz) (Nujoma, 2001), as well as the copper deposits at Matchless (in 1850) near Ai-Gams (Windhoek), at Khan (in 1905) near Swakopmund, and Tsumeb (in 1906) in northern Namibia (Schneider & Seeger, 1992).

Colonial mining operations in Namibia date back to the 19th century when the country was known as German South-West Africa (Schneider & Seeger, 1992; Cairncross & Moir, 1996). The first copper ore under German colonial rule came from Onganja Mine (Westphal, 1914) in central Namibia, which produced modest concentrates of less than several hundred tonnes per year. The concentrates were exported to Germany with ox-wagons, railway and ships via Swakopmund (Hegenberger, 1981). However, the Tsumeb Mine, which was in operation from 1906 to 1996, dominated copper production in the colonial period. Significant amounts of copper production were also obtained from the Khan Mine of the Khan-Kupfergrube-Gesellschaft and the other OMEG mines at Kombat, Matchless and Otjihase (Schneider & Seeger, 1992).

The recorded copper production from South-West Africa up to the time of independence in March 1990 amounted to 1.508 Mt or 83% of the total copper production from Namibia up to today (Fig. 6.1). In terms of monetary value, this colonial production is worth US$ 5,652 billion at constant US$ 1998 prices. The indigenous people did not benefit from this wealth, instead they lost their traditional homelands as well as control over the natural resources that occurred there (Nujoma, 2001). They were forcibly removed from their homelands and herded into "native reserves". Those who were employable were turned into a captive workforce of labouring slaves, until they regained their freedom and independence in 1990 as a result of the armed struggle waged by SWAPO.

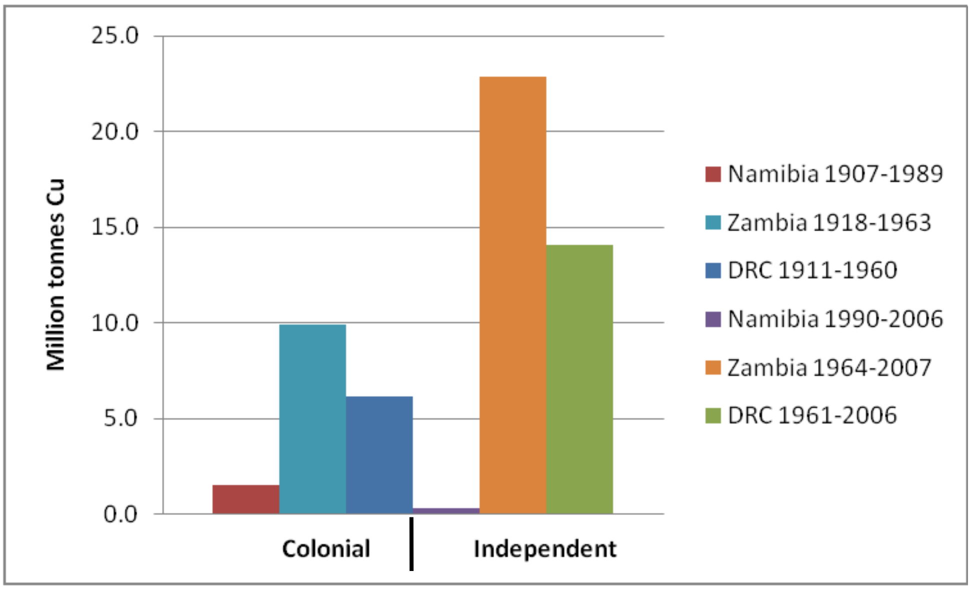


Figure 6.1: Comparison of copper production during the colonial and independent periods in Namibia, Zambia and the DRC.

By the time Namibia became an independent country in March 1990, there was very little copper remaining at Tsumeb and the other mines (Kombat, Matchless, Otjihase) such that only 300,300 t of copper metal worth US$ 784.5 million were produced up to 2006 (Fig. 6.1). The tax revenues and royalties from this and other mining activities, especially diamond and uranium mining, have been used to develop schools, hospitals, housing and roads in various parts of the country, especially northern Namibia which was completely neglected during colonial rule.

With perhaps the exception of the Haib prospect in southern Namibia, few primary reserves of copper remain. However, new technology can bring the waste and slag heaps of the old mining and smelting districts like Tsumeb (Fig. 6.2) again into production for base metals (Zn, Cu, Pb, V) and rare metals (Ge, Ga, In, Au, Ag) that were not fully recovered in the past. In addition, bio-leaching technology (Mining Review Africa, 2005) can now be applied to low-grade copper deposits, such as the Haib copper porphyry which contains 0.37 % Cu only, but has huge volumes of ore.

Unfortunately, the fall in metal prices in 2008 has resulted in mine closures and postponement or termination of many extensive exploration programmes for base metals, diamonds and gold, which were partly driven by the rise in world commodity prices since 2006. However, new uranium mine development and new value-added gemstone cutting and polishing, metal-processing, and other mineral-based manufacturing industries could maintain the mineral sector's position as a significant contributor to Namibia's economy for the foreseeable future.

Major constraints to mineral development include the lack of water resources, as well as the availability of fuel and electric power. It is therefore important for Namibia to develop the Kudu Gas Field and to introduce nuclear electricity-generation. In addition, investments in the transportation infrastructure (roads, railways, airports and naval ports) should be made, so that inter-regional trade can be accelerated in the SADC region.

Figure 6.2: Part of the old tailings impoundment in the Tsumeb Smelter Area viewed from the south. Fine-grained tailings (pinkish brown) are partly covered by coarse-grained fractions of slag mill tailings (black) to suppress dust (Kříbek & Kamona, 2005).

6.2.2 Zambia

Commercial copper production in Zambia became established between 1918 and 1931 (Mendelsohn, 1961). By 1957 most of the major copper deposits had been discovered and production levels went above 400,000 tpa from 1956 onwards, to reach a record colonial production of 632,353 t in 1964 (Table 4.3). The total amount of copper metal produced in the colonial era from 1918 to 1964 amounted to 10.5 Mt, which is estimated to be equivalent to US$ 36.329 billion based on constant US$ 1998 prices. In contrast, independent Zambia produced a total of 22.2 Mt of copper metal (Fig. 6.1) estimated at US$ 80.97 billion.

During the colonial era the African miners gradually organised themselves into a mine workers movement and went on strike for the first time in 1935 and in 1940 to protest against their exploitation under slave-like working conditions and racial discrimination (Musole, 1962). These strikes were met with the full brutal force of the colonial government, which killed a number of workers, but the strikes eventually led to better working conditions and the recognition of African trade unions by the mining companies in 1949. The awakening of the class consciousness of the miners culminated in the three week strike of 1952, in which about 39,000 miners took part and, to quote (Musole, 1962) "the miners demanded wage increases, for the capitalists had been making tremendous profits and paying out large sums in dividends abroad".

The continued resistance of the mine workers to the colonial exploitation eventually resulted in further strikes being organised by the African Mine Workers Union in 1955 and 1956, which resulted in the declaration of a 'state of emergency' and the arrest of the leaders of the African Mine Workers Union and the African National Congress. The significance of these strikes is that they resulted in the international recognition of the Mine Workers' Union by the World Trade Union movement, who organised substantial donations from abroad, including from British trade unions (Musole, 1962), to support the miners' struggle against the imperialist exploiters. Eventually, the trade union movement was affiliated to the mass political movement of Northern Rhodesia, resulting in independence from the imperial United Kingdom in October, 1964 when Kenneth Kaunda became the first Zambian president.

Under President Kaunda's socialist government, the mines were nationalised in 1970 in order to utilise the mineral earnings to develop other sectors of the Zambian economy, especially education, health, transport and agriculture. However, reinvestment in the mining industry was neglected, leading to a progressive decline in revenue and copper production (Fig. 4.4) from the record high of 748,122 t in 1969 to a low of

390,600 t in 1991 (Table 4.3). The economic deterioration of the Zambian economy in this period eventually led to a new market-oriented government taking over power under President Frederick Chiluba in 1991.

The new government privatised ZCCM, the largest enterprise in the minerals sector, under pressure from IMF and the World Bank, who made privatisation of ZCCM a condition attached to several loans from both these institutions. It was also a pre-condition for Zambia to qualify for debt relief through the highly indebted poor countries (HIPC) initiative (Fraser & Lungu, 2007). Between 1997 and 2000 ZCCM's assets were split into seven sections and sold to various investors, though the company was able to retain shares in some of the units – including in KCM – through the creation of a holding company called ZCCM-Investment Holdings (ZCCM-IH) (Dymond, 2007; Fraser & Lungu, 2007).

Privatisation of the mines was supposed to save the government money and also generate resources from increased investments by the new owners, who would then generate significant profits that would be channelled back to the government through taxation and dividends (Dymond, 2007). However, the mining companies obtained 15 to 20 year contracts that allow the exploitation of copper resources on unfavourable terms, including the very low mineral royalty of 0.6% of the gross revenue of minerals negotiated by most mining companies, including KCM, despite the Mines and Minerals Act of 1995 specifying that mineral royalties should be set at 3% for companies holding large-scale mining licences (Fraser & Lungu, 2007).

In general, as pointed out by Fraser and Lungu (2007), privatisation has been disappointing for the Zambian people, since the new mining companies are not obliged to provide social infrastructure such as jobs, schools, hospitals and HIV/AIDS prevention programmes, which was previously the responsibility of ZCCM. In addition, there are few opportunities for local staff to step into management positions and to receive advanced training. Furthermore, the collapse of ZCCM procurement and sales procedures, which were designed to increase linkages to the local economy, has resulted in the demise of local enterprises in preference to suppliers, manufacturers and markets outside Zambia.

The positive impact of privatisation include significant investments that have re-invigorated the mining industry and resulted in increased production levels to above 400,000 tpa since 2003 and to more than 500,000 tpa from 2006 onwards (Table 4.3). However, production levels are expected to fall in the near future due to the decline in copper prices.

6.2.3 The DRC

King Leopold II commissioned the American correspondent Henry Stanley to make treaties with native chiefs that enabled the former to obtain personal title to the so-called territory of the Congo Free State at the Berlin Conference in 1885 (InformationPlease, 2008). The brutal colonial rule of Leopold, during which more than 10 million people are estimated to have lost their lives through forced labour, starvation and extermination, eventually, in 1908, prompted the Belgium parliament to compel the King to cede the Congo Free State to Belgium to become a colony. It was forthwith known as Belgian Congo, and remained a colony until June 30, 1960 when Independence was obtained.

During the colonial exploitation of the Congo, a total of 6.09 Mt of copper metal (Fig. 6.1) worth US$ 20.5 billion was produced between 1911 and 1960. In contrast, 14.02 Mt of copper worth US$ 51.7 billion were produced in the period following Independence from 1960 to 2006. Thus, much more copper has been produced in this period compared to the colonial era, a fact which probably indicates why the DRC has found little peace ever since the assassination of the leftist Comrade Patrice Lumumba, the first Prime Minister of the Congo, in 1960 by a Belgian mercenary, after the mineral rich Katanga Province seceded from the new Republic (InformationPlease, 2008).

It is heartening to note that new technology is being applied by Malta Forrest in conjunction with STL to extract Cu, Co and Zn from the slag heap, locally known as "The Big Hill" at Lubumbashi (Fig. 6.2). According to Dr. Jacques Cailteux (pers. comm., 2007), the slag hill contains 294,400; 102,041 and 61,950 tonnes of Zn, Co and Cu respectively, originating from previous mining operations by Union Minière du Haut Katanga and Gécamines. Although the DRC is regarded as one of the most prospective countries in Africa in terms of her mineral potential (Engineering & Mining Journal, 2000), further economic development in the DRC is hampered by the lack of peace and the poor infrastructure. However, just like in Zambia, the state has now allowed the private sector to participate in the mining industry, which was previously monopolised by Gécamines, the state mining enterprise. It still remains to be seen whether the net result of privatisation will benefit the people of the DRC or the mining companies.

Figure 6.3: View of the STL slag hill in Lubumbashi, March 2007.

6.3 Potential Economic Benefits From Copper Production in Namibia, Zambia and the DRC

Mining has the potential to increase economic development in an area more than agriculture, due to the associated infrastructure required to support mining operations (e.g. roads and railways, schools, hospitals, housing) and auxiliary industries that supply power, mining and plant machinery, and spare parts. For every job generated in the mining industry, three more jobs are created in the auxiliary industries. Consequently, mining in the three countries led to an upsurge in the use of electricity, which had a direct benefit to other sectors, including local businesses, farmers, educational institutions and municipalities that operated in the mining areas.

Table 6.1 and the accompanying charts in Figure 6.3 show the usage of electricity in SADC countries. The use of electricity is a direct index to the level of development in a country. Namibia's use of electricity at 0.6 billion kilowatt-hours (kWh) for a population of 2 million people amounts to a per capita value of 300 kWh, which is a much higher index than other countries with larger populations (Fig. 6.3; Table 6.1). In comparison, South Africa has the highest per capita value of 3965 kWh, whereas Zambia consumes 640 kWh per capita, and the DRC has the lowest value in the SADC region of 9.17x10-8 kWh per person. The per capita kWh values also indicate where investments in the energy sector for the domestic population is needed most. Consequently, the level of development and benefits to the local populations as a result of copper mining in Namibia and Zambia is more substantial than in the DRC.

Table 6.1. Use of electricity in the SADC region (after Winter, 2008)

Country	Use of electricity in billion kWh	Population	Per capita kWh
Angola	1.8	11,200,000	160.7
Botswana	1.6	1,448,000	1105.0
DRC	5.5	60,000,000	9.17×10^{-8}
Lesotho	0.2	2,090,000	95.7
Malawi	0.9	1,090,000	82.6
Mauritius	1.1	1,168,000	941.8
Mozambique	1	18,614,000	53.7
Namibia	0.6	2,000,000	300.0
Seychelles	0.1	79,000	1265.8
South Africa	174.5	44,000,000	3965.9
Swaziland	1.1	1,000,000	1100.0
Tanzania	1.6	32,000,000	50.0
Zambia	6.4	10,000,000	640.0
Zimbabwe	8.4	12,000,000	700.0

With improved electricity generation, industries other than mining also become cheaper to run, and in turn the general development of the country improves. In this context it can be clearly seen that in the SADC region, countries without major mining industries have lower electricity generation and consumption per capita than those with mining industries (Table 6.1). The only exceptions are the small island nations of the Seychelles and Mauritius which depend heavily on tourism. Countries like Tanzania, Mozambique, Angola and Malawi do not seem to have benefitted as much from the infrastructural development resulting from mining operations. This can be attributed to the fact that other sectors like agriculture and tourism are more dominant in Tanzania and Malawi, whereas the long years of armed struggle in Angola and Mozambique made it difficult to develop the infrastructure.

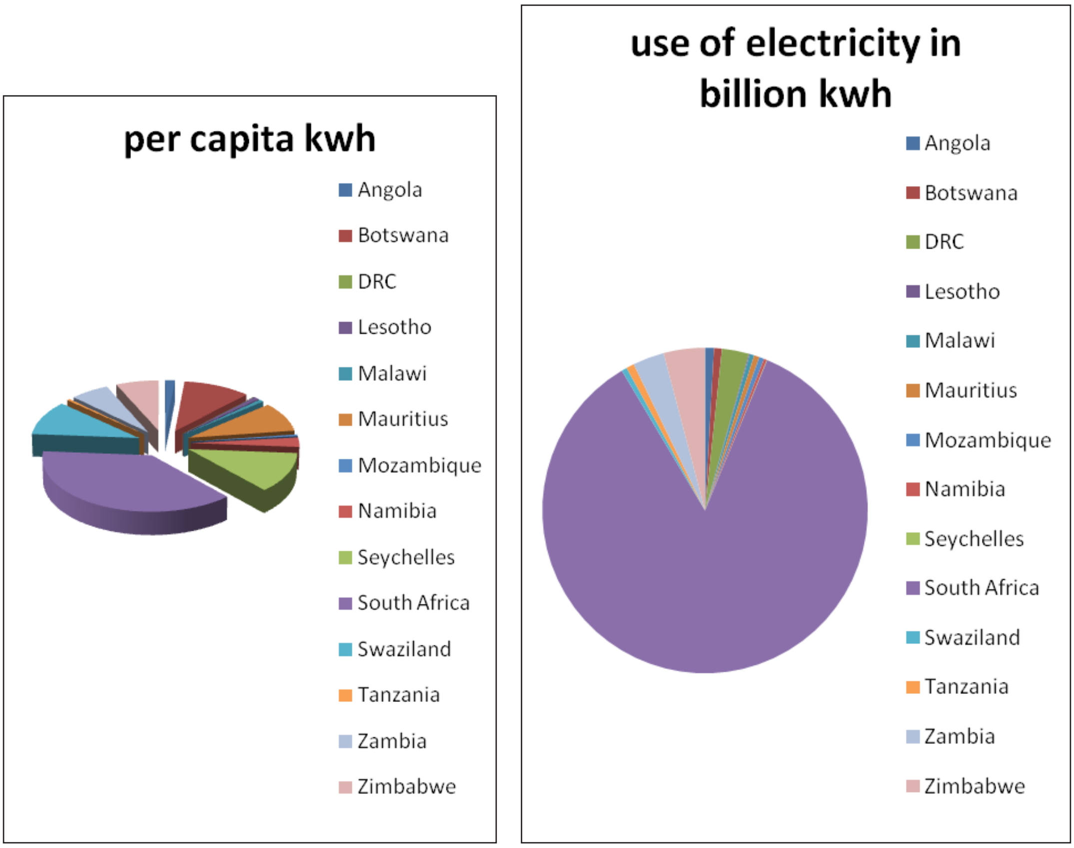


Figure 6.3: (a) Use of electricity in the SADC region in billion of kilowatt hours. (b) The same data is now represented per capita to show the developmental index or access to electricity in each country.

Other indirect benefits that emanate from mining operations, such as the emergence of commercial business and industrial centres, housing and retail markets, and business in general develop in areas where mining operations are concentrated. However, the lack of downstream industries which could add value to the mined commodities, especially copper, is a major drawback to economic development in the region. This situation denies the local population more employment opportunities and the potentially significant financial benefits from the sale and marketing of processed products, while major value addition and hence profits are made in manufacturing countries elsewhere.

The road and railway transport networks which are constructed as a result of mining activities have the potential of becoming the arteries of industrial development in the SADC region. All major mining centres in the region are well linked by rail and/or road, but this infrastructure is not well maintained in many countries, with the exception of Namibia, where the roads and railways are constantly upgraded. This has been a major incentive to development in the Otavi Mountainland, where copper production was centred for a long time.

The few benefits that accrued to the Congo were the erection of buildings and factories, and the establishment of roads in Katanga that were, however, poorly maintained. These meagre advantages were overshadowed by the fact that a few people enriched themselves, and worst of all, the national treasures for the whole of the DRC were not used for the benefit of the people. One therefore wonders whether the endowment of rich copper deposits in the DRC was a blessing or a curse.

The author has hope for the future of the DRC, as there are still enough reserves in some of the richest copper ore deposits in the SADC region, such as Tenke-Fungumire, and the country possesses the largest hydropower potential on the African continent. With a vast surface area comparable to western Europe, and abundant rainfall all year round, the DRC has to be one of the most blessed countries, whose potential just requires the right political leadership to unlock it for the benefit of the people.

If secondary downstream industries of copper had been established in the DRC after Independence, it is likely that skills development and manufacturing of secondary products from copper would have resulted in the DRC being one of the strongest economies in Africa. Skills developed through manufacturing are more likely to have spinoffs, as new items may be made by the same work force. It is sad, and at the same time remarkable, that the need for the DRC's cobalt in the west, especially in the United States of America, in a de-facto manner determined both the domestic and foreign policy of Zaire under President Mobutu Seseseko.

The economic decline of Zaire resulted in most of the intellectuals leaving the country for Europe (mainly France and Belgium), Canada and the United States of America in search of better livelihoods. These intellectuals could have been instrumental in the development of the DRC. In the meantime, new cadres have to be trained in all aspects of human endeavour to develop the country.

6.4 Life After Mining

A concept of future planning to ensure the survival of mining towns after mine closures is proposed. All mining towns and mining entities need to plan for the time when the ore will be exhausted, and find ways of sustaining the economic activities of the town. These initiatives ought to involve the mine workers themselves and auxiliary institutions such as town councils and municipalities. Some of the initiatives that can be undertaken are in the development of new skills for young people; establishing of downstream industries that manufacture goods from metals produced and agriculture with its attendant industries in food processing.

A good example of ensuring benefits to local communities after mining has stopped, has been shown by Albidon Limited of Canada, at their Munali Nickel project (Fig. 6.5). This project was initiated in 2007, and at inception, Albidon decided that the labour workforce originating from the local area would benefit from the presence of the mine at Munali.

Figure 6.4: (a). The author at the entrance to the new decline of the Munali Nickel project in Zambia with Dr. Sixtus Mulenga (Manager, Albidon Zambia Limited). (b) View of the agricultural plots offered to the Munali Nickel project workers in 2007.

All the local farmers who were displaced by the mining project were relocated and offered new pieces of land bought for them by Munali Nickel. In addition, those willing to work for the mine were offered employment. Small farm holdings were also bought for mine employees interested in small scale agricultural activities that could sustain them even after mine closure. Seed funding was provided for them in the form of seeds, tractors hired by the company, and agricultural expertise to support the employees in the first year of their farming ventures. Albidon Zambia Limited is indeed an example of a modern mining company showing responsible mining strategies that consider the local community.

CHAPTER 7: RECOMMENDATIONS AND CONCLUSIONS

7.1 Recommendations

In view of the foregoing, a number of recommendations may be considered as follows:

7.1.1 Copper manufacturing

Investments should be made in mills and fabricating plants to produce finished copper products such as wire cables and ingots which are required in various industrial applications, including telecommunications, construction, motor vehicles, electronics and computers. It is recommended that these manufacturing plants should buy the copper metal directly from smelters and refineries in the SADC region with a view to produce such finished products. Economic benefits from such investments will include economic sustainability even after mine closure, provision of employment, wealth creation by export of manufactured goods, and the development of a regional market for copper metal. In the short term, investments can be made at the ZAMEFA fabricating plant to expand its operations to cater for the SADC region.

It could also be recommended that some of the copper produced in the SADC region could be stockpiled for future use. Such stockpiles could form reserves for the coming generations who would then be assured of the availability of copper in the future. However, this would require funds to be set aside for such an undertaking, as the mining will cost money, but no income will be generated through sales. It could therefore also be considered to formulate policies or enact legislation, under which certain amounts of copper would remain in the ground un-mined, and therefore be available for future generations. In addition, governments and regional organisations should promote investment in research centres to develop new products and applications based on finished copper products.

7.1.2 Closed copper mines

Some of the famous mines that are now closed, such as the Tsumeb Mine in Namibia and Kipushi in the DRC, could still continue to provide some income for the local communities if they were to be maintained as museums for both local and international tourists. These mine museums would also serve an educational purpose as examples of past mining operations for future generations.

Government intervention is required to support investments and development of industries that can sustain themselves after mine closures. One way to achieve this is by setting aside a percentage of the proceeds from mining ventures into a trust for the purpose of investing in industries that can ensure the continuity of economic activity after mine closure.

7.1.3 Small scale mining

A number of copper deposits may not be attractive to large mining companies because of their small size, but such deposits may be exploitable on a small scale for the local supply of ore to a larger enterprise as is the case with the artisanal miners in the DRC. It is therefore recommended that the occurrence and distribution of small copper deposits be properly documented and assessed for exploitation by members of local communities. The community members should be provided with the necessary background information and knowledge, as well as basic training in mineral resource exploration and mining to enable them to work safely with due regard to the environment. In this regard it is recommended that Ministries of Mines in the SADC region could work closely with academic institutions in their respective countries to provide the needed support to local communities.

In addition proper safety and health regulations should be put in place to check the working conditions of all mining related activities, especially the small scale miners, who sometimes operate illegally with no benefits from a well regulated mining industry.

7.1.4 Waste dumps

Waste dumps from copper mines, and indeed even other metal mines, are potential new mines for metals such as Ge, Ga, In and Zn which were not completely recovered from the ores of polymetallic deposits like Tsumeb and Kipushi. Some of these rare metals can still be exploited as a result of technological improvements in processing of waste materials as is currently done at the STL plant in Lubumbashi, for example.

7.1.5 Archaeometallurgy

The multi-disciplinary field of archaeo-metallurgy, which includes geology, mining engineering, materials science, archaeology and anthropology, should be included in university geology and engineering courses, so that the history of indigenous technological enterprise finds its rightful place in African history.

7.2 Conclusions

Copper mining in the DRC, Namibia and Zambia has taken place for many centuries, starting with mining of copper oxide ores that ushered in the Bronze Age. The processing of copper by ancient civilizations in the Middle East and later in Egypt provided a technological basis for metallurgical processing of ore deposits and contributed to industrialisation in many countries worldwide. In the DRC, Namibia and Zambia, the known copper occurrences which were worked by the local communities in the past made it easier to locate new deposits when Europeans began exploring for mineral deposits towards the beginning of the 19th Century.

Despite the billions of dollars generated from copper mining during the colonial era, the indigenous miners lived in poverty and remained poor as they were employed mainly for menial work for which there were few benefits apart from the low wages they received. The incidental benefits that were "inherited" after the political struggles for independence came by default, in the form of the infrastructure built to facilitate copper mining and export to markets in Europe and the USA. The substantial profits that the colonial mining companies made from mining the copper resources by using cheap African labour led to the inevitable entrenchment of colonial rule, which made it difficult for the oppressed people of Namibia, Zambia and the DRC to free themselves from the yoke of colonialism.

Even after independence the copper mines have continued to produce considerable wealth, particularly in Zambia and the DRC, the two major copper producers in Africa. However, much of this wealth does not directly benefit the local communities due to the export-oriented structure of the mining industry in Africa.

Concerted efforts by governments and regional organisations should be made to take advantage of the available copper resources by developing manufacturing plants to produce finished goods for local and international consumption. The downstream manufacturing plants will offer economic sustainability to mining towns after mine closures. Such plants can source the copper metal from other operating mines in the region and thus continue to create employment, generate wealth and promote industrial development in line with Namibia's and Zambia's Vision 2030.

REFERENCES

- Adamson, R.G., & Teichmann, R.F.H. (1986) The Matchless cupreous pyrite deposit, South West Africa/Namibia. In: Anhaeusser, C.R. and Maske, S. (Eds.), Mineral Deposits of southern Africa, Geol. Soc. S. Afr., v. II, 1755-1760 pp.
- AdeAjayi, J.F., & Crowder, M. (1985). Metal Technology and the Bantu people; in: Historical Atlas of Africa, Longman.
- African Economic Outlook (2008). Zambia. www.oecd.org. Accessed 9 March, 2009.
- Albidon (2007). Code of conduct. Unpublished company brochure, Albidon Zambia Limited, January 2007.
- Alexander, W., & Street, A. (1976). Metals in the service of man. Penguin Books Ltd. 346 pp.
- Angermeier, H.-O., Kraub, U., Kruszona, M., & Schmidt, H. (1974). Rohstoffwirtschaftliche Länderberichte III Zaire. Bundesanstalt für Bodenforschung, Hannover, 120 p.
- Barnes, K. (n.d.). The treasures of “the hole which falls in”. Unpublished report.
- Beaumont, P.B. (1973). The ancient pigment mines of southern Africa. South African Journal of Science, 69, 140-146.
- Binda, P.L. (1995). Reflections on metallogenic models for sediment-hosted stratiform copper deposits. In: Wendorff, M. And Tack, L. (Eds.), Late Proterozoic belts in central and southwestern Afdrica. Royal Museum of Central Africa, Tervuren, Belgium, Annals Science Geology, V. 101, p. 77-86.
- Borg, G. (1995). Metallogenesis of Neoproterozoic basins in Namibia and Botswana. Communications of the Geological Survey of Namibia, V. 10, p. 109-119.

- Borg, G. (2000). Regional controls on sediment-hosted Pb-Zn (Ba-Cu) occurrences within the Pan-African orogenic belts of Namibia. Communications of the Geological Survey of Namibia, V. 12, p. 211-220.
- Boshier, A.K. (1965). Ancient mining of Bomvu Ridge. Scientific South Africa, 2, 317-320.
- Bowen, R., & Gunatilaka, A. (1977). Copper: its geology and economics. Applied Science Publishers, Ltd., London, 366 pp.
- Boyle, R.W., Brown, A.C., Jefferson, C.W., Jowett, E.C., & Kirkham, R.V. (Eds.) (1989). Sediment-hosted stratiform copper deposits. Geological Association of Canada, Special Paper 36.
- Breitkopf, J.H., & Maiden, K.J. (1988). Tectonic setting of the Matchless Belt pyritic copper deposits, Namibia. Economic Geology, 83, 710-723.
- Cailteux, J. (1988). Estimation E 296 des réserves géologiques entre les niveaux 1150 et 1300 à Kipushi. Gécamines Geological Department (Likasi, DRC), unpublished report (R.A. 948).
- Cailteux, J.L.H., Kampunzu, A.B., Lerouge, C., Kaputo, A.K., & Milesi, J.P. (2005a). Genesis of sediment-hosted stratiform copper-cobalt deposits, central African Copperbelt. Journal of African Earth Sciences, 42, 134-158.
- Cailteux, J.L.H., Kampunzu, A.B., & Batumike, M.J. (2005b). Lithostratigraphic position and petrographic characteristics of R.A.T. (“Roches Argilo-Talqueuses”) Subgroup, Neoproterozoic Katanga Belt (Congo). In : L.Robb, J.Cailteux and S. Sutton (Eds.), Recent advances in the geology and mineralization of the Central African Copperbelt. Journal of African Earth Sciences, 42, 82-94.
- Cairncross, B., & Moir, S. (1996). Famous Mineral Localities: The Onganja Mining District, Namibia. The Mineralogical Record, 27, 85-98.
- Carr, G.R., Dean, J.A., McAndrew, J., Gulson, B.L., Korsch, M.J., & Mizon, K.J. (1986). A comparative study of the Pb isotopic compositions of Cu and Co mineralization, basement rocks and gabbros from the Copperbelt and ``Domes’’

regions of Northern Zambia. Unpublished Report, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Sydney, Australia.

- Chetty, D., & Frimmel, H.E. (2000). The role of evaporites in the genesis of base metal sulphide mineralisation in the northern platform of the Pan-African Damara Belt, Namibia: geochemical and fluid inclusion evidence from carbonate wall rock alteration. Mineralium Deposita, 35, 364-376.
- Clark, J.G.D. (1959). The Prehistory of Southern Africa. Penguin, London.
- Codelco (2007). Press release, March 2007, http://www.codelco.cl. Accessed 28 March, 2007.
- Cook, C.K. (1963). Report on the excavations at Pomongwe and Tshangula caves, Matopo Hills. South African Archaeological Bulletin, 18, 147-150.
- Copper Development Association (2009a). The Sumereans and Chaldeans. http://www.copper.org/education/history/60centuries/ancient/thesumerians.html. Accessed 21 February, 2009.
- Copper Development Association (2009b). Copper production from ore to finished product. www.copper.org/education/production. Accessed 6 February, 2009.
- Copper Resources Corporation (2005). Copper Resources acquires option on the Haib copper project in Namibia. Press release May 2005, http://www.copperresources.com. [Accessed: 28 March, 2007].
- Dart, R.A. (1934). The discovery of Stone Age manganese mine at Chowa, Northern Rhodesia. Transactions of the Royal Society, South Africa, 22, 55-70.
- Dart, R.A., & Beaumont, P. (1969). Evidence of Iron Ore Mining in Southern Africa in the Middle Stone Age. Current Anthropology, 10, 127-128.
- De Magnée, I., & François, A. (1988). The origin of the Kipushi (Cu, Zn, Pb) deposit in direct relation with a Proterozoic salt diapir. Copperbelt of Central Africa, Shaba, Rep. of Zaïre. In: Friedrich, G.H., Herzig, P. M. (Eds.), Base metal sulfide deposits, Springer-Verlag, Heidelberg, 74-93.

- De Vos, W., Viane, W., & Moreau, J. (1974). Minéralogie du gisement de Kipushi, Shaba, Zaïre. In: Bartholomé, P. (Ed.), Gisements stratiformes et provinces cuprifères. Centenaire de la Société Géologique de Belgique, Liège, 165-183.
- Drechsier, H. (1996). Südwestafrika unter deutscher Kolonialherrschaft. Franz Steiner Verlag, Stuttgart.
- Dymond, A. (2007). Undermining development? Copper mining in Zambia. www.actsa.org/Pictures/UpImages/pdf/. Accessed 10 March, 2009.
- Emerging Metals Limited (2008). The Tsumeb slag stockpiles project. http://www.emergingmetals.com/Projects.html. Accessed 6 February, 2009.
- Engineering and Mining Journal (2000). Current status of mining in the Democratic Republic of Congo, p.20-26.
- Equinox Minerals (2008). Lumwana copper mine. www.mining-technology.com/projects/lumwana. Accessed 6 February, 2009.
- Evans, M.E. (1993): Ore geology and industrial minerals. Blackwell Science. 389 pp.
- Fleischer, V.D., Garlick, W.G., & Haldane, R. (1976). Geology of the Zambian Copperbelt. In: Wolf, K.H., Handbook of stratabound and stratiform ore deposits, Amsterdam, Elsevier, V. 6, p.223-352.
- François, A. (1974). Stratigraphie, tectonique et minéralisations dans l'arc cuprifère du Shaba (Rép. du Zaïre). In: Bartholomé (Ed), Gisements stratiformes et provinces cuprifères. Centenaire de la Societé Géologique de Belgique, Liège, 79-101.
- François, A. (1987). Synthèse géologique sur l'arc cuprifère du Shaba (Rép. du Zaïre). Centenaire de la Société Belge de Géologie, 15-65.
- Franklin, J.M., Sangster, D.M., & Lydon, J.W. (1981). Volcanic-associated massive sulfide deposits. Economic Geology, 75th Anniversary Volume, 485-627.
- Fraser, A., & Lungu, J. (2007). For whom the windfalls? Winners and losers in

the privatisation of Zambia's copper mines. www.minewatchzambia.com. Accessed 9 February 2009.

- Galley, A.G., Hannington, M.D., & Jonasson, I.R. (2007). Volcanogenic massive sulphide deposits. In: Goodfellow, W.D. (Ed)., Mineral Deposits of Canada: A Synthesis of Major Deposit-Types, District Metallogeny, the Evolution of Geological Provinces, and Exploration Methods: Geological Association of Canada, Mineral Deposits Division, Special Publication No. 5, p. 141-161.
- Gebhard, G. (1999). Tsumeb II. 328 pp. GG Publishing, Grossenseifen, Germany.
- Geological Survey of Namibia (1992): The Mineral Resources of Namibia. Geological Survey of Namibia, Ministry of Mines and Energy, Namibia.
- Geological Survey of Namibia (2006): Base metals. http://www.mme.gov.na/gsn/basemetals.htm. Accessed 9 February 2009.
- Guilbert, J.M., & Park, C.F (1986). The geology of ore deposits. W.H. Freeman and Co., 985 pp.
- Gunning, H.C. (1961). The early years. In: Mendelsohn, G. (Ed.), The Geology of the Northern Rhodesian Copperbelt. MacDonald, London, pp. 3-10.
- Gustafson, L.B., & Hunt, J.P. (1975). The porphyry copper deposit at el Salvador, Chile. Economic Geology, 70, 857-912.
- Gustafson, L.B., & Williams, N. (1981). Sediment-hosted stratiform deposits of copper, lead and zinc. Economic Geology, 75th Anniversary Volume, 139-178.
- Hälbich, I. (1968). Onganja concession, Okahandja-Windhoek districts. Final Report for the period 1966 to 1968. Unpublished Report, Tsumeb Corporation Ltd.
- Hartmann, P.W. (1986): The role of mining in the economy of South West Africa/Namibia – 1950 to 1985. M.Sc thesis, University of Stellenbosch, 370 pp.,
- Hegenberger, W. (1981). Onganja copper belt of central South West Africa/Namibia. Unpublished report, Geological Survey of Namibia, Windhoek.

- Henry, G., & Wilson, M.G.C., (2006). Copper and Cobalt deposits in the SADC Region. Council for Geoscience, Pretoria. http://www.sadcreview.com.
- Herbert, E.W. (2003). Red Gold of Africa: Copper in pre-colonial History and Culture. Second Edition, Madison, University of Wisconsin Press, 2003, 438p.
- Hughes, M.J., Welke, H.J., & Allsop, H.L. (1984). Lead isotopic studies of some Late Proterozoic stratabound ores of Central Africa. Precambrian Research, 25, 137-139.
- Hutchinson, R.W. (1980). Massive base metal sulphides deposits as guides to tectonic evolution, In: Strangeway, D.W. (Ed.), The continental crust and its mineral deposits, 659-684, Geological Association of Canada, Special Paper 20.
- IISD (2002). Seven questions to sustainability: how to assess the contribution of mining and minerals activities. Task 2 Work Group, Mining, Minerals and Sustainable Development North America, International Institute for Sustainable Development, pp. 66. [downloadable on www.iisd.org]
- InformationPlease (2008). Democratic Republic of the Congo. www.infoplease.com. Accessed 11 February 2009.
- Innes, J., & Chaplin, R.C. (1986). Ore bodies of the Kombat Mine, South West Africa/Namibia. In: Anhaeusser, C.R. and Maske S. (Eds.), Mineral deposits of southern Africa, Geological Society of South Africa, II, 1789-1805.
- Intiomale, M.M., & Oosterbosch, R. (1974). Géologie et géochimie du gisement de Kipushi, Zaire. Centenaire de la Société Géologique de Belgique, Gisements stratiformes et Provinces cuprifères, 123-164.
- Kamona, A.F. (2003). Genetic models of Proterozoic carbonate-hosted base metal sulphides deposits in central-southern Africa. In: Cailteux, J. (Ed.), Proterozoic sediment-hosted base metal deposits of western Gondwana, Conference and Field Workshop, IGCP 450, Lubumbashi, Democratic Republic of Congo, p. 160-162.

- Kamona, A.F., & Günzel, A. (2007). Stratigraphy and base metal mineralization in the Otavi Mountain Land, northern Namibia: a review and regional interpretation. Gondwana Research, 11, 396-413.
- Kamona, A.F., Lévêque, J., Friedrich, G., & Haack, U. (1999). Lead isotopes of the carbonate-hosted Kabwe, Tsumeb, and Kipushi Pb-Zn-Cu sulphide deposits in relation to Pan African orogenesis in the Damaran-Lufilian fold belt of Central Africa. Mineralium Deposita, 34, 273-283.
- Kamona, F., & Friedrich, G. (1994). Die Blei-Zink-Lagerstätte Kabwe in Zentral Sambia. Erzmetall, 47, 34-44.
- Kamona, F., & Friedrich, G.H. (2007). Geology, mineralogy and stable isotopes geochemistry of the Kabwe carbonate-hosted Pb-Zn deposit, Central Zambia. Ore Geology Reviews, 30, 217-243.
- Kampunzu, A.B., Cailteux, J.L.H., Kamona, A.F., Intiomale. M.M., & Melcher, F. (in press). Sediment-hosted Zn-Pb-Cu deposits in the Central African Copperbelt. Ore Geology Reviews.
- Killick, A.M. (2000). The Matchless Belt and associated sulphide mineral deposits, Damara Orogen, Namibia. Communications of the Geological Survey of Namibia, V. 12, pp. 73-80.
- Kinahan, J. (1980). Eighteenth century copper smiths in central Namibia: comments on some sources and syntheses. Namibiana, 2, 17-22.
- Kinahan, J. (1991). Pastoral nomads of the Central Namib deseert: the people history forgot. Windhoek, New Namibia Books and Namibia Archaeological Trust.
- Kinahan, J., & Vogel, J.C. (1982). Recent copper working in the Kuiseb drainage, Namibia. South African Archaeological Bulletin, 37, 44-45.
- Kirkham, R.V. (1989). Distribution, settings, and genesis of sediment-hosted stratiform copper deposits. In: Boyle, R.W., Brown, A.C., Jefferson, C.W.,

Jowett, E.C., and Kirkham, R.V. (Eds.), Sediment-hosted stratiform copper deposits. Geological Association of Canada, Special Paper 36, p. 3-38.

- Kříbek, B., & Kamona, F. (Eds.) (2005). Assessment of the mining and processing of ores on the environment in mining districts of Namibia. Final report for the year 2004 - Tsumeb Area. Prague, Czech Geological Survey, Record Office - File Report No. 2/2005.
- Kuntz, J. (1904). Copper ore in South West Africa. Transactions of the Geological Society of South Africa, 7, 70-76.
- Lau, B. (1987): The Matchless Copper Mine in 1857. 113 pp., Charles John Andersson Papers, Vol. 1, Archaia 7, Windhoek.
- Lombaard, A.F., Günzel, A., Innes, J., & Kruger, T.L. (1986). The Tsumeb lead–copper–zinc–silver deposit, South West Africa/Namibia. In: Anhaeusser, C.R., Maske, S. (Eds.), Mineral Deposits of Southern Africa, Geological Society of South Africa, vol. II, pp. 1761–1787.
- Magadza, C.H.D. (2006). Kariba reservoir: experience and lessons learned brief. http://www.ilec.or.jp/eg/lbmi/pdf/14_Kariba_Reservoir_27February2006.pdf. Accessed 19 March, 2009.
- Mambwe, S.H., Simukanga, S., Sikazwe, O.N., & Kamona, F. (Eds.) (1995). 1995 International Conference on Industrial Minerals: investment opportunities in southern Africa. AGID Zambia and Council for Geoscience South Africa, 374 pp.
- McKinnon, D.M., & Smit, N.J. (1961). Nchanga. In: Mendelsohn, G. (Ed.), The Geology of the Northern Rhodesian Copperbelt. MacDonald, London, pp. 234-275.
- Mendelsohn, F. (1961). The geology of the Northern Rhodesian Copperbelt. Macdonald, London, 523 pp.
- Miller, D. (1995). 2000 years of indigenous mining and metallurgy in southern Africa – a review. South African Journal of Geology, 98, 232-238.

- Miller, D., & Sandelowsky, B. (1999). Smelting without ceramics: the Drierivier copper smelting site near Rehoboth, Namibia. South African Archaeologcial Bulletin, 54, 28-37.
- Miller, D.E., & Kinahan, J. (1992). The metallurgical analysis of copper beads and ore from archaeological sites in central Namibia. Communications of the Geological survey of Namibia, 8, 67-79.
- Miller, D.E., & Van der Merwe, N.J. (1994). Early metal working in sub-Saharan Africa: a review of recent research. Journal of African History, 35, 1-36.
- Miller, D.E., Young, S.M.M., Green, W.A., van der Merwe, N.J., & Sandelowsky, B. (2005). Sourcing the ore from the Drierivier copper smelting site in cewntral Namibia, using lead isotope finger printing. South African Journal of Science, 101, 1-3.
- Miller, E.W.B. (1980). Onganja Mine-M46/3/131. Unpublished report. E.W.B. Miller & Associates (Pty) Ltd., 11p.
- Mines Directorate (1992–2000). Annual reports of the office of the Chief Inspector of Mines/Government Mining Engineer, Windhoek. Unpublished government reports.
- Mining Review Africa (2005). Lowering the cut-off grade for copper projects. Issue 2, 32-33.
- Ministere Des Mines et Des Affaires Foncieres (n.d.). Recapitulation du tonnage des Principaux produits Miniers extraits au Congo Depuis L'Origine, Bulletin 547.
- Minnitt, R.C.A. (1986). Porphyry copper-molybdenum mineralization at Haib river, South West Africa/Namibia, 1567-1585. In: Anhaeusser, C.R. and Maske, S. (Eds.), Mineral deposits of Southern Africa II. Geological Society of South Africa, 2335 pp.
- Musole, J.W. (1962). Class struggles in Zambia. Http://www.disa.ukzn.ac.za. Accessed 9 February, 2009.

- Nujoma, S. (2001). Where others wavered: the autobiography of Sam Nujoma. London, Panaf Books.
- Pieenar, P.J. (1961). Bwana Mkubwa area. In: Mendelsohn, F. (Ed.), The Geology of the Northern Rhodesian Copperbelt. Macdonald, London, p. 467-484.
- Richards, J.P., Cumming, G.L., Krstic, D., Wagner, P.A., & Spooner, E.T.C. (1988). Pb isotope constraints on the age of sulphide ore deposition and U-Pb age of late uraninite veining at the Musoshi stratiform copper deposit, Central Africa Copper Belt, Zaïre. Economic Geology, 83, 724-741.
- Rimann, E. (1915). Geologische Untersuchungen des Bastardlandes in Deutsch-Sudwestafrika. D. Reimer, Berlin, 100pp.
- Robb, L.J., Armstrong, R.A., Master, S. & Rainaud, C. (2003). Chronological constraints on the genesis of stratiform Cu-Co mineralization in the Katangan of central Africa and implications for models of ore formation. In: Cailteux, J. (Ed.), Proterozoic sediment-hosted base metal deposits of western Gondwana, Conference and Field Workshop, IGCP 450, Lubumbashi, Democratic Republic of Congo, p. 135-137.
- Ruxton, P.A. (1986). Sedimentology, isotopic signature and ore genesis of the Klein Aub copper mine, South West Africa/Namibia. In: Anhaeusser, C.R., Maske, S. (Eds.), Mineral Deposits of Southern Africa, Geological Society of South Africa, vol. II, pp. 1725–1738.
- SADC Review (2008). SADC Review 11th Anniversary: 1997-2008. www.sadcreview.com. Southern African Marketing Co. (Pty) Ltd & SADC Secretariat. Accessed 12 March, 2009.
- Sandelowsky, B.H. (1974). Pre-historic metal-working in south West Africa. Journal of the South African Institution of Mining and Metallurgy, 74, 363-366.
- Sandelowsky, B.H., & Pendelton, W.C. (1969). Stone tuyères from South West Africa. South African Archaeological Bulletin, 24, 14-20.

- Sawkins, F.J. (1990). Metal deposits in relation to plate tectonics. 2nd edition, Springer-Verlag, Berlin-Heidelberg, 461 pp.
- Schneider, G.I.C. (1998): History of Mining in Namibia. Namibia Brief, 21, 19-31, Namibia Foundation, Windhoek.
- Schneider, G.I.C. (2004): The Roadside Geology of Namibia. Sammlung Geologischer Fuehrer 97, 294 pp., Gebrueder Borntraeger (Berlin, Stuttgart).
- Schneider, G.I.C., & Seeger, K.G. (1992). Copper. In: The mineral resources of Namibia, Geological Survey of Namibia, p. 2.3-1 – 2.3-117.
- Schneider, J., Melcher, F., & Brauns, M. (2007). Concordant ages for the giant Kipushi base metal deposit (DR Congo) from direct Rb-Sr and Re-Os dating of sulphides. Mineralium Deposita, 42, 791-797.
- Scott, S.D. (1989). Precambrian massive Cu-Zn-Pb sulfide ores of North America. A short course on "characteristics of sulfide and exploration for massive sulfide deposits, Aachen, Germany, 1-122.
- Scudder, T. (2005). The future of large dams: dealing with social, environmental, institutional and political costs. Earthscan, London, 389 pp.
- Sharpe, J.W.N. (1962). Report of Exploration Grant Area M4/4/98 for the period 1st September, 1961 to 31st March 1962. Unpublished Report. Emka Mining & Trading Company (Pty) Ltd., 3p.
- Stanczak, M. (2005). A brief history of copper. http://www.csa.com/discoveryguides/ copper/overview.php. Accessed 21 February 2009.
- Strauss, S.D. (1986): Trouble in the third kingdom. Mining Journal Books Limited, London, 227 pp.
- Sweeney M.A., Binda PL, & Vaughan, D.J. (1991). Genesis of ores of the Zambian Copperbelt. Ore Geology Reviews, 6, 51-76.
- Sweeney, A.M., & Binda, P.L. (1994). Some constraints on the formation of the Zambian Copperbelt deposits. Journal of African Earth Sciences, 19, 303-313.

- The State of the Environment in the Zambezi Basin (2000). A report by the Southern African Development Community (SADC-ELMS and WSCU). Southern African Research and Documentation centre-Musokotwane Environment Resource Centre for Southern Africa (SADRC-IMERCSA).
- Trifonov, D.N., & Trifonov, V.D. (1985). Chemical elements: how were they discovered. MIR Publishers, Moscow, 264 pp.
- U.S. Geological Survey (1964). Minerals Yearbook 1942: Copper, p. 127-161. http://digital.library.wisc.edu/1711.dl/EcoNatRes. MinYB1942. Accessed 20 January 2009.
- U.S. Geological Survey (2008). Copper statistics, in Kelly, T.D., and Matos, G.R., (comps.), Historical statistics for mineral and material commodities in the United States: U.S. Geological Survey Data Series 140, available online at http://pubs.usgs.gov/ds/2006/140/. (Accessed 9 February, 2009).
- U.S. Geological Survey (2009). Mineral commodity summaries 2009: U.S. Geological Survey, 195 p.
- United Nations Institute for Namibia (1987). Namibia: legal framework and development strategy options for the mining industry. Duggai, N.K. (ed.), United Nations Institute for Namibia, Lusaka, 176 pp.
- USAGOV (2009). Democratic Republic of the Congo. http://www.state.gov. Accessed 12 March, 2009.
- Van der Merwe, N.J., & Scully, R.T.K. (1971). The Phalaborwa story: archaeological and ethnographic investigation of s South African Iron Age group. World Archaeology, 3, 179-202.
- Wakefield, J. (1978). Samba: a deformed porphyry-type copper deposit in the basement of the Zambian Copperbelt. Transactions of the Institute of Mining and Metallurgy, 87B, 42-52.
- Wartha, R.R., & Genis, G. (1992). Lead and zinc. In: The Mineral Resources of Namibia. Geological Survey of Namibia, p. 2.5-1–2.5-43.

- Weatherly (2008). Weatherly International PLC. http://www.weatherlyplc.com. Accessed 12 March, 2009.
- Webster's New World Dictionary of the American language. (1957). The new World Publishing Company, Cleveland and New York, 1724 pages.
- Wendorff, M. (2003). Stratigraphy of the Fungurume Group – evolving foreland basin succession in the Lufilian fold-thrust belt, Neoproterozoic - Lower Palaeozoic, Democratic Republic of Congo. South African Journal of Geology, 106, 47-64.
- Westphal, H. (1914). Die Kupfererz-pegmatite von Otjizongati (Deutsch-Südwest-Afrika). Zeitschrift für Praktische Geologie. Berlin 22, 385-416.
- Winter, K. (2008). Oxford Intermediate Atlas for Southern Africa. Oxford University Press, Southern Africa, Cape Town, 64 pages.
- World Factbook (2009). https://www.cia.gov/library/publications/the-world-factbook/index.html. Accessed12 March, 2009.