disappointing with the highest values being 0.49% Zn over 0.5m, and 320ppm Cu and 156ppm Mo over less than 0.5m.

7 Ferrous Metals Fe, Mn, Ti, V

7.1 Introduction

Zambia possesses an abundance of iron deposits of various types and attention has been directed to them on a number of occasions as a basis for a domestic iron and steel industry. In addition to fairly extensive investigations by larger companies including Anglo-American and Rio Tinto in the 1940s to 1960s, the skarn-type deposits south of Mumbwa were investigated by Yugoslav parastatal Geozavod in 1966–1967, and a joint UNDP-Mindeco programme focused on iron deposits during 1969–1973. Reports on all these studies are available at the Geological Survey Department and are listed in the bibliography.

Considerable discussion in recent years has revolved around whether domestic consumption in Zambia could support a limited iron and steel industry, particularly in view of the fact that the distance to any port largely rules out any export potential outside Africa. Consumption was estimated to be 150,000 tonnes of iron in 1999 (ECL, 1999), up from 70,000 tonnes of iron per year in 1965 (Watts, Griffis and McOuat, 1991), but the latter authors concluded that this requirement could be met by the established ZISCO plant in Zimbabwe and imports from the Republic of South Africa.

Despite these earlier negative prognostications, a number of developments since 1991 have placed the concept of domestic iron production in a more favourable light. The privatisation of the copper industry has seen major external investment into Zambia, and an increasing demand for iron and steel in the mining sector, across the construction and manufacturing industries, and in other areas of domestic activity. At the present time this demand has been met by imports from South Africa and Zimbabwe, and there are plans to create an iron and steel industry in neighbouring Mozambique. Zambia possesses an abundance of iron ore deposits and sufficient resources of limestone and energy are available to create its own iron and steel industry. Given its enviable political stability and position in Central Africa the country could meet its own domestic requirements and supply its neighbours with products from the iron and steel industry. However, the distance to ports is too great to allow the development of a large export-based industry and future prospects must depend on the continuation of economic growth and stability.

Three types of iron occurrence can be recognized in Zambia: sedimentary ironstone, skarn and replacement deposits and laterite. With only one exception (the Kampumba deposit), the larger deposits are confined to Katanga Supergroup rocks and commonly to units equivalent to the Mine Series Group (Lower Roan) (Figure 27). Key features of the more important deposits are presented in Table 23 taken from Watts, Griffis and McOuat (1991).

7.2 Sedimentary Ironstone Deposits

This group includes the massive and locally brecciated haematitic deposit of Nambala, a 300m-high ridge located approximately 20km south of Mumbwa, which is part of a discontinuous curvilinear line of ironstone ridges that extends for a distance of 24km (Phillips, 1955 and 1957; Dawson, 1974). Variations in the types of sedimentary deposits include the massive haematite beds intercalated with conglomerate and arkose at the Kasumbalesa deposit north of Chingola (Stohl, 1980) to the magnetite-quartzites of Mutombe and Pamba, 45km west of Lusaka (Stohl, 1977).

Table 23 Principal iron deposits in Zambia

Deposit	Geology	Million Tonnes	% Fe
Chibote	Ironstone	50.0	61.0
Mlembo	Haematite replacement of Katanga shales	15.0	44.2
Kasumbalesa Group	Haematite beds in L. Roan	5–8	60–68
Chisasa Group	Haematite and magnetite replacement of L. Katanga sediments adjacent to syenite and gabbro	7.4	58.8
Kasempa Group	Replacement adjacent to Hook Granite Complex	229.0	66.0
Lubungu	Ironstone and vein, breccia and skarn deposits in Roan and Kundelungu	175.0	56.6
Karenda Group	Haematite and magnetite in Kundelungu arenites; fault breccias; skarns related to felsic porphyry and syenite	15.0	40–60
Nalusanga Group	Katanga Group ironstone, vein and skarn deposits associated with Hook Granite Complex	43.0	49–61
Nambala	Haematitic ironstone, Kundelungu Group; minor skarn associated with syenite	200.0	57.0
Shimyoko Group	Replacement and minor vein deposits related to syenite and diorite	3.9	56–59
Namakumbo Group	Skarns related to syenites; ironstone	>32.0	30–60
Namantombwa Group	L. Katanga; banded ironstone, skarn and replacement associated with syenite and gabbro	38.7	50–60
Mutombe–Pamba Group	Magnetite iron-formation and ferruginous quartzite	>31.0	30–49
Nampundwe	Stratiform pyrite-magnetite in L. Katanga limestone-shale sequence	19.8	50–60
Sanje Group	Replacement deposit in L. Katanga limestone adjacent to syenite; minor ironstone also	9.3	62–67
Chongwe Group	Sedimentary ironstone, L. Katanga	10.0	65.0
Kampumba	Haematite replacement body in Muva limestone Mn-rich at surface	56.0	61.0

7.3 Synsedimentary Exhalative Pyrite Deposits

The Nampundwe deposit, 24km west of Lusaka (see Section 5.4.2), is a stratiform pyrite-magnetite deposit in a Lower Katanga carbonate-dominated sequence. It is mined as a source of sulphur for the manufacture of sulphuric acid used in processing the Copperbelt ores and a small amount of the magnetite is used for heavy media flotation at Maamba Collieries. Production is about 70,000t of pyrite and 1000t of magnetite per annum.

The orebody has all the characteristics of stratabound sedimentary exhalative deposits (SEDEX) with a series of stratabound, massive sulphide lenses hosted by a thick sequence of massive dolomites (Burnard, 1990). The mineralisation occurs as eight, folded sub-vertical sheets extending up to 6km along strike and over 300m down dip. The orebodies pinch out and interdigitate extensively with black shaley dolomite. Sedimentary structures, such as slumping, channel infill, soft sediment boudinage and rip-up clasts, have been described. The mineralogy varies between different sheets with some being dominated by pyrrhotite (up to 70% of the rock) with minor pyrite, chalcopyrite and sphalerite, and others by massive pyrite, with minor pyrrhotite and chalcopyrite. There is also one thin, discontinuous chalcopyrite sulphide band grading 5–7% Cu. Magnetite occurs in small amounts in the sulphide ore and disseminated in the host footwall dolomites. Sulphur isotopes indicate a mixed origin of the sulphur between light sulphur of hydrothermal origin and heavy seawater sulphur (Burnard et al., 1993). All of the above features are typical of SEDEX deposits of the Besshi-type, which are dominated by iron sulphides with lesser copper and zinc.

Correlation of the stratiform pyrite deposit at Nampundwe with the stratabound iron oxide deposits in the Katanga stratigraphic sequence has not been attempted but it is possible that the sulphide-ores are the proximal part of the hydrothermal system and the oxide ores formed distally. Exploration potential exists for the discovery of further stratiform massive sulphide deposits and some of these may be richer in copper, zinc or nickel.

7.4 Skarn and Replacement Iron Deposits

These deposits are commonly associated with syenitic and granitic, less commonly gabbroic or doleritic, bodies that have intruded the iron-rich units of the lower Katanga Supergroup. Such deposits are particularly numerous around the northern and eastern margins of the Hook Granite Complex and satellitic syenite bodies and include the Kasempa, Lubungu, Karenda and Nalusanga groups of deposits (Stohl, 1975). They variously comprise massive replacement bodies in arenites and numerous breccia and vein deposits, together with skarn deposits, which are more typical of the Nalusanga area. Pyrite is a common component of the skarns, occasionally accompanied by minor copper sulphides. South of Mumbwa towards Kafue Flats, the Shimyoko, Namakumbo and Namantombwa groups are mostly skarn and replacement bodies associated with the numerous small syenite stocks, 0.5–2km in diameter, that have intruded lower Katanga limestones, dolomites and arenites. Minor pyrite and chalcopyrite have been reported in a number of the deposits.

The Mlembo deposit in Central Province, 85km NNW of Serenje, is a more enigmatic deposit comprising a 150–180m-thick unit of massive haematite which is believed to be a replacement product of shale within a sequence of Katanga arenites (Dawson, 1974). The Kampumba deposit, 65km ESE of Kabwe, is a more typical replacement deposit hosted by limestone but, unusually, the limestone is of Muva age (Watts, Griffis and McOuat, 1991). Also, the surface and near-surface part of the orebody is manganese enriched, containing 30–50% Mn, although at depth the body comprises massive haematite, minor magnetite and only a few veinlets of manganese minerals. A supergene origin for the near surface deposits is indicated but the original protoliths were probably a manganiferous carbonate and iron-enriched schists.

7.5 Supergene Manganese Deposits

There are many occurrences of surficial manganese mineralisation in Zambia and they occur in a wide variety of stratigraphic and tectonic settings. Several have been worked in the past for chemicals and for dry cell batteries. The main deposits were the Mansa area (Bahati and Mashimba), Chiwefwe, Kampumba, and Lubemba. However, the demand was never very large and most of the deposits were worked from shallow pits and opencasts. Two or three styles of mineralisation are present; surface incrustations, veins and stratiform accumulations, and all three can be grouped as products of supergene enrichment (Green and Daly, 1982). Supergene enrichments can be expected in many parts of Zambia because of the long weathering period during the early Tertiary, when the central African peneplain or erosion surface was formed. A manganese-enriched precursor is probably not essential, but larger deposits will form where there is some original pre-concentration or protolith. The protolith may be a volcanic tuff or lava, a chemogenic deposit of banded Fe and Mn-rich oxide layers or a manganiferous carbonate rock. The attitude of the protolith may determine the form of the deposit; where the rock is shattered or mylonised the deposit will become irregular, vertical veins; where the protolith is a steeply dipping, massive bed they will become surface encrustations and; where shallow dipping, stratiform replacements.

Prospects for development of new manganese deposits are not high, but there may be local demand for manganese minerals in a resurgent copper smelting industry that could easily be met from existing deposits.

7.5.1 Stratiform Manganese Deposits

Stratiform manganese deposits can form where highly oxygenated meteoric water reacts over a long period with slightly Mn-enriched rocks. Such conditions existed during Tertiary times when a long period of weathering caused the central African peneplain to be developed. Surface encrustations form as supergene deposits on the surface of a pre-existing manganese-rich precursor, which in the case of the Kampumba deposit is a manganiferous dolomite and at Chiwefwe a series of phyllites and quartzites. Whilst a number of deposits have been worked in Zambia the total production has probably been only 0.5Mt and it is unlikely that large scale mining of manganese will take place in the near future. However, there may be a local demand for material in a developing chemical and metallurgical industry.

The Kampumba orebody forms a residual capping over the outcrop of a steeply dipping band of meta-dolomite intercalated in a sequence of quartzites and schists. The dolomitic marble contains rhodochrosite and this can be seen passing into braunite and then psilomelane. Flanking zones of iron ore appear also to be residual, but derived from magnetite-bearing schist rather than dolomite. The deposit was discovered in 1903 and first explored as an iron ore prospect, but has produced 300,000 tons of ore at grades between 50 and 54% Mn.

At Chiwefwe the deposits occur in several sheet-like rubble bodies running along the edge of a quartzite ridge and overlying a slightly manganiferous sequence of Muva age phyllites and psammites. Production between 1954 and 1963 was 77,416 tons at a grade about 45% Mn, and there is probably a large amount of ore remaining in the area.

On the Copperbelt, beds of impure psilomelane occur in sericite schist at Luano, near the northern margin of the Nchanga Red Granite. The mineralisation is stratabound and occurs in a 1.5m thick bed with grades of 39 to 48% Mn. The ‘bed’ thickens at depth to 16.5m but the grade decreases to only 13% Mn and the richer material appears to lie near the surface. Total production was about 10,000 tons and the ore was used in copper refining at the Nchanga mine.

The Mutembula area described by Green and Daly (1982) is a stratabound manganese occurrence occurring in rhyolitic tuffs of Muva age. The tuffs are variably enriched in either manganese or iron and range from 42% Mn (with 1% Fe_2O_3) to 2% Mn (with 36–39% Fe_2O_3). This shows clear evidence for chemical enrichment at the time of deposition with alternating bands enriched in manganese or iron. However, unlike the supergene-enriched ores, which are relatively soft and easy to work, bedded deposits, such as Mutembula, have not been worked.

7.5.2 Vein-style Manganese Deposits

Vein style deposits are typically seen at Mansa where the manganese oxides, predominantly psilomelane, occur in many small N–S veins. The relationship to the host rocks is difficult to determine but the veins appear to follow quartz veins and mylonitic rocks suggesting supergene enrichment down pre-existing brittle fractures and shear zones. The veins are hosted by granite and contemporaneous volcanics and neither are noticeably enriched above the 600ppm Mn crustal average. The veins contain psilomelane, hausmannite, manganite and pyrolusite. Other minerals present in the veins are quartz, baryte and fluorite. The orebodies are almost vertical, pinching and swelling from a few centimetres up to several metres (average width about 1m). Most of the ore is near surface and pinches out below 50m depth. Their strike length is also variable with some veins extending to nearly a kilometre. Production in the period 1953 to 1961 totalled 77,630 tons at a grade of around 48 to 50% Mn.

7.6 Magmatic ilmenite deposits

Titanium deposits have not been worked in Zambia and there are few records of any exploration being undertaken specifically for this purpose. Titanium has now become a more important metal for industrial use, particularly in the aerospace industry, and, also, in the form of its oxide as a white pigment in paint. Two minerals are sought rutile and ilmenite, with the former predominantly being recovered from heavy mineral beach sands and the latter from mafic intrusions. Exploration potential exists for the ilmenite in some of the intrusive rocks of eastern Zambia but, with the availability of abundant beach sand deposits in neighbouring Mozambique and South Africa, their exploration potential must remain limited. Rutile is also found in eclogitic rocks where it is the product of ilmenite breakdown under high pressure conditions and some eclogitic rutile deposits are worked in Norway.

One ilmenite occurrence has been described in Eastern Province at Chinkombe, where a sheared ultramafic or mafic body has been converted into a talc-anthophyllite-ilmenite rock. Analysis of the ilmenite (Table 24, taken from Reeve, 1963, p.163) shows it is a suitable product for conversion into a Fe-Ti alloy. As far as is known there has been no further examination of this locality. However, the inaccessibility and remoteness of the location, 58km north of Petauke, argues against its potential, when the cost of transport to a processing plant is considered.

Ilmenite occurs in the conglomerates of Mumpuwe Lume Hill, north of Mkushi, close to the border with the D.R.Congo (Njamu and Chikwekwe, 1993). A further enigmatic titanium occurrence, just south of Chinsali, is known as Torrs Mine but no further information on the deposit or its working could be found.

Table 24 Analyses of ilmenite samples from Chinkombe, Eastern Province

	Sample 1	Sample 2	Sample 3
TiO_2%	44.00	43.76	42.86
FeO%	32.71	32.47	28.20
Fe_2O_3%	20.95	21.35	27.13
MnO%	0.35	0.33	0.31
CaO%	0.04	0.03	0.31
MgO%	1.56	1.17	1.21
Total	99.61	99.11	99.73

Source: Reeve (1963)

8 Ni, Cr and Platinum Group Elements

This group of elements occurs predominantly in mafic igneous rocks, where the initial concentrating mechanism is the separation of either an immiscible nickeliferous sulphide phase from a basic magma, or the crystallisation of an early chrome spinel. Concentrations of platinum group elements (PGEs) can occur by both methods and be upgraded by secondary hydrothermal processes. Platinum deposits are worked in Zimbabwe where they occur in the Great Dyke, which extends across the country before dying out to the north as it reaches the Zambezi Belt. The distribution of cobalt and nickel occurrences in the country is shown in Figure 28.

A number of gabbro and serpentinite bodies occur in the Zambezi Belt to the south and east of Lusaka and their stratigraphic position is unclear. The gabbros at Munali seem to be intrusive into the Katangan but the serpentinite bodies may be part of oceanic crust formed in a small back arc basin, either in the Muva period or in an interval around 800Ma when the Kafue bimodal volcanics were formed, and later incorporated into the Zambezi Belt (Figure 19).