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).

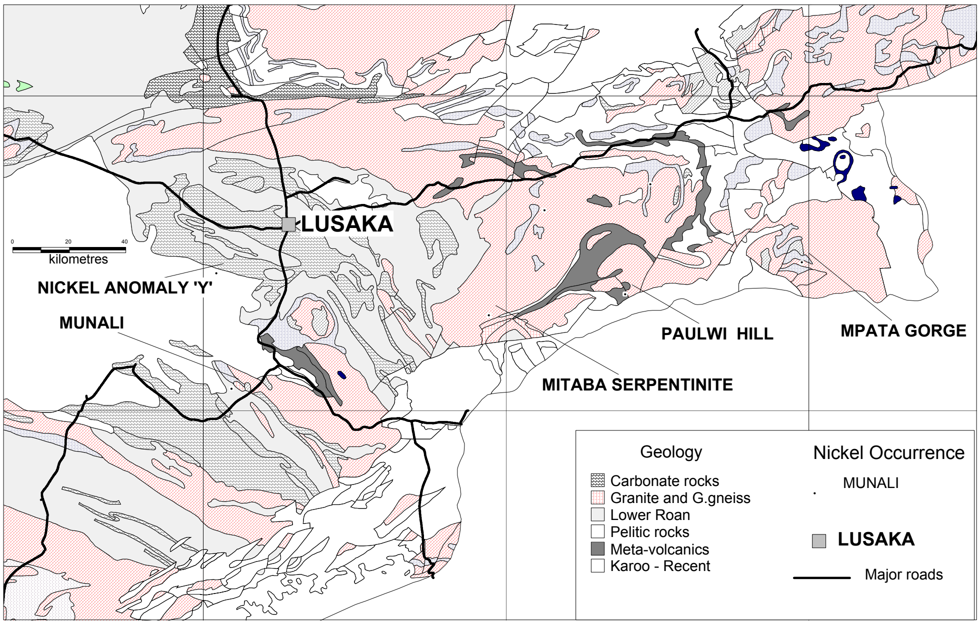

Figure 19 Nickel occurrences in the Zambezi Belt, south of Lusaka

8.1 Magmatic nickel deposits

Magmatic nickel deposits form in large gabbro and ultramafic intrusions by the separation of an immiscible sulphide melt, which concentrates the chalcophilic elements from the magma. In some cases the sulphide may be supplied by the ingestion of sulphide-bearing sediments and contaminated norites produced which can contain appreciable copper and nickel. This class of contaminated magmatic deposit is related to skarn or metasomatic deposits, where the magma reacts with a carbonate or sulphide-bearing host to a mafic intrusion. The Munali deposit is of this category, so is included here, even though the mineralisation is not contained in the source gabbro.

8.1.1 Zambezi Belt deposits

Munali Hills

The Munali deposit is located in the Munali Hills approximately 64km by road SSW of Lusaka. The mineralisation comprises pyrrhotite, pentlandite and minor pyrite in an alteration zone in schists and limestones around the intrusive Munali gabbro (Diedrix, 1978; Mambwe, 1989a). The alteration zone is about 100m wide at surface and has been traced along strike for a distance of about 830m. A gossan extends down to 40m depth and a zone of supergene enrichment exists below this where violarite is the main nickel-bearing phase. Zamanglo drilled some 68 holes in 1970–1974, totalling some 21,636m, and proved the mineralisation at >1% Ni for up to 30m in thickness. The nickeliferous zone narrows to about 5m at a depth of 500m. An indicated resource of 2.06Mt grading 1.1% Ni and 0.16% Cu has been estimated, together with an additional inferred resource of 8.36Mt at 1.13% Ni and 0.16% Cu (Watts, Griffis and McOuat, 1991). Precious metals (palladium-rich) were reported at 3.5g/t of concentrate (at 3% Ni). However, metallurgical testing concluded that, using a feed grade of 1% Ni, a concentrate of only 3% Ni is produced and that attempts to raise the concentrate grade resulted in nickel recoveries of less than 50%. The bulk test sample was from the supergene-enriched zone and therefore may not be representative of the mineralogy of the orebody at depth.

Mitaba

Located 90km south-east of Lusaka, the deposit was discovered in 1957–8 by regional stream sediment and airborne surveys, and followed up by mapping, soil sampling and trenching (Hale and Freeman, 1971). Detailed work over the anomalous Mitaba area, identified during the regional survey, consisted of 384 stream sediment samples (values up to 2,200ppm Ni) over $10km^2$, grid soil sampling done at

15m intervals, along lines 150m apart. The highest values returned were related to the serpentinite and ranged from 0–700ppm Ni in soils over the country rock and from 700–6,000ppm Ni over the intrusives (with a peak of 10,000 ppm Ni). Cu and Zn values were generally low, ranging from 10–130ppm for Cu and from 10-150ppm for Zn. A more detailed grid (7.6m intervals, with lines 30m apart) was sampled and the best Ni values, of between 0.60 and 1.30%, again occurred over the serpentinite. Ground IP and geomagnetic surveys were conducted to trace potential sulphide mineralisation, and to outline targets for trenching.

Thirty-one trenches were excavated, and many results obtained ranged up to between 1.0-1.25% Ni over 3.0-21.3m (average 5m). A total of 365m of wagon drilling was completed in 29 holes, about 15m apart, over the soil anomalies. Ni values ranged from 0.50–1.00% from surface to about 3m, but tended to decrease to between 0.30–0.40% Ni below this. Finally, 12 diamond drill holes (from 152-213m deep) were put down to test complete sections of the ultrabasic body. Very little visible Ni sulphide mineralisation was intersected and the average Ni values in the serpentinite were 0.30–0.40% down to about 91m. The best results intersected ranged from 0.60-0.71% Ni over a maximum of 3m drilled thickness. Only trace sulphides were detected by drilling – pyrite, pentlandite and pyrrhotite on joint planes. There appears to be little significant sulphide mineralisation, but the area may have potential as a laterite Ni deposit (see below). The possibility of chromite and PGE mineralisation should not be ignored.

Paulwi Hill

Located 50km east of Mitaba and 120km ESE of Lusaka, the mineralisation is hosted by serpentinised dunite, which is part of the pyroxenite-dunite-gabbro Paulwi Hill ultramafic complex (Abbey and Von Holt, 1972; Watts, Griffis and McOuat, 1991).

Regional mapping of the Rhodesia Minerals Concession Area by Garlick and Skerl in 1932 outlined the Paulwi Hill ultrabasic complex and a sample of the serpentinite returned an assay of 1.2% Ni. Panning of a nearby stream draining the ultrabasic complex yielded chromite grains but no further work was done in the area until regional airborne geomagnetic and radiometric surveys were carried out in 1959–60. Operations were suspended until 1964, when the whole area was covered by a stream sediment sampling program (samples taken at 400m intervals). Silt samples were analysed geochemically for Cu, Ni, Zn and Pb and the panned concentrates were scanned spectrographically for 18 elements. Six low level Cu anomalies were located, but only two of these anomalous areas had related Ni.

The best of these two anomalies was located at Paulwi Hill, where Ni drainage values up to 3,600ppm were found over an area of 5,000 x 3,000m. Low levels of Zn, Pb, Cr and Mo were also found in the area. At Paulwi Hill, soil sampling, geological mapping and magnetic, EM, SP and IP geophysical surveys were conducted over the Ni occurrence. In 1967, soil sampling was again carried out, followed by trenching (over 4,000m), which intersected up to 2.0% Ni over 10.7m. A later drilling programme consisting of 16 diamond drill holes (totalling 2,582m). The best sulphide (predominantly pyrrhotite) intersections were 0.9m at 0.45% Ni and 0.21% Cu and 1.5m at 1.00% Ni and 0.10% Cu. Finely disseminated pyrite and pyrrhotite are present but the nickel (0.2–0.3%) is mostly present as micron-sized grains of nickel in silicate minerals. Reported trench values of up to 2.0% Ni are probably a product of superficial enrichment.

The nickel appears to occur only in silicate form and no significant Ni sulphide mineralisation is present. Enough work has been done on this prospect to conclude that economic Ni mineralisation will probably not be found. The only high Ni concentrations were found at surface, and this was due to surface enrichment, and has no economic impact. However, the area contains a number of ultrabasic bodies, and it could be looked at in more detail for other ultramafic-related minerals, such as chromite, PGEs and, possibly, emeralds.

Mpata Gorge

Located 160km ESE of Lusaka, this geologically complex area includes norite and gabbro bodies, which may, possibly, be faulted extensions and remnants of Zimbabwe's Great Dyke (Watts, Griffis and McOuat, 1991).

The area was first mapped on a reconnaissance scale by Rhodesian Mineral Concession Ltd and futher prospecting by Charter Exploration Ltd took place from 1958 to 1959. This consisted of mapping and photogeological interpretation, with drainage sampling at 400 m intervals over 368km^2 (2,389 samples analysed for Cu, Zn, Pb and Ni). The only anomaly of interest was a belt of Ni values between 100 and 2,000ppm and associated Cu values of 70–120ppm in streams in an area of 15 x 6.5km in which hypersthene norites and diorites were known. Zamanglo Exploration Ltd. in 1972 started with stream geochemistry and, completed drainage and soil sampling of the Kamalenzi blocks covering the nickel anomaly. Work was halted in the first quarter of 1973 because of the security problem of Zambia's southern border. Low level radiometric surveys were flown by Saarberg in the late 1980s. Soil geochemistry anomalies (>80ppm Ni) are associated with ultrabasic rocks, with five anomalies >1000ppm Ni and a maximum of 3650ppm Ni.

Nickel Anomaly 'Y'

Situated 27km southwest of Lusaka, anomaly 'Y' comprises concentrations of nickel associated with veinlets and sulphide disseminations in a serpentised gabbro-peridotite complex intruded into shaley carbonaceous limestone or dolomite.

This Ni anomaly was within the original King Edward (Nampundwe) PL 35, and was found during regional exploration over the area, by Zamanglo Exploration Ltd. and Chartered Exploration Ltd. during 1964–75 (other prospects in the area had been worked since the turn of the century by early prospectors). By 1967, the systematic regional soil sampling program had progressed far enough west to cover the area where the Ni anomaly was eventually identified. Also in 1967, an airborne electromagnetic and magnetic survey was flown over the central part of PL 35, and. in 1969, a United Nations airborne EM survey covered part of the King Edward PL. Numerous anomalous areas identified by these surveys (including Ni anomaly 'Y') were followed up by ground geophysics, geochemical sampling, geological mapping, pitting, trenching and diamond drilling.

Nickel anomaly 'Y' was first investigated as a copper prospect, which partly overlaps the Ni anomaly in the northeast corner. Ni prospecting started in 1971, and consisted of detailed geological mapping, trenching, geophysics and diamond drilling. A total of 14 trenches were excavated near a brecciated contact zone between a basic-ultrabasic intrusive and limestone/dolomite. Trench results were disappointing, returning highest assays of only 0.43-0.55% Ni over 3m (in 5 of the trenches). Geophysical surveys consisted of Turam, magnetometer and IP. The magnetic and IP surveys identified two anomalous zones within the intrusive that could have been the result of sulphides. Two holes were drilled in the southern corner of the intrusive; but the intercepts of interest were all in gabbro and were low grade. The best intersection, out of both holes, assayed 0.9% Ni and 0.04% Cu from 50.8-51.1 m.

8.2 Copper-Nickel stratabound deposits

8.2.1 Kalumbila and Kimale

These two metasediment-hosted deposits are both located in the Domes Region of North Western Province. The Kalumbila deposit, near the south-east corner of the Kabompo Dome, comprises pentlandite, pyrrhotite and chalcopyrite hosted by an 11km-long shale unit thought to belong to the Mwashia Formation overlying the Upper Roan (Appleton, 1978). The nickel mineralisation occurs as lensoid bodies, which are assumed, but not proven, to be conformable with the host shale. The deposit is believed to be associated with a gabbro body, which could be the source of the mineralisation but this has yet to be confirmed.

The Kalumbila prospect was originally called the Mushingishi property (MO 526) by Guernsey (1941), who reported that Du Plessis excavated five trenches on the property. Auger drilling by Mwinilunga Mines outlined a large copper geochemical anomaly (more than 3,000ppm Cu) over a strike length of 1,600m, with anomalous Ni and Co at the north-east end.

In 1958, geological and geochemical fieldwork done by Roan Selection Trust delineated an anomalous area about 11km long and from 600–1,200m wide. The anomaly consists of three zones; a nickel, a copper, and a nickel-cobalt zone. Drilling of the anomaly commenced in 1959, and by the end of 1960, four holes (out of several drilled along 2,500 m of strike) had intersected 0.91% Cu over 4m to 1.75%

Cu over 10m at depths of 100–300m below surface. In 1961, four more holes were drilled to test for down-dip extensions, and returned results of 0.3% Cu over 0.8m to 1.32% Cu over 9m. Nickel values grading up to 0.24% over 2m were intersected in the most northeasterly holes on the copper anomaly. At the Ni-Co anomaly, 0.34% Ni over 4m, with 0.36% Co and 0.41% Cu, was the best drill intercept.

During the end of 1961 and early 1962, results from one hole drilled into the Ni anomaly returned 0.93% Ni over 26m (with 0.3% Co and 0.16% Cu), with a peak of 3.35% Ni over 2.3m, at a depth of about 300 m. From 1962–64, an additional 10 holes were drilled. The holes were spotted to intersect the mineralisation at depths of 200–500 m, and were spaced from 150–300m apart, along about 2,000m strike length. A total of 31 holes were drilled between 1959 and 1964. Limited metallurgical testwork carried out on the core indicated that good recoveries of Ni in a high grade concentrate was possible with simple sulphide flotation.

Resource estimates for four zones were as follows:

1. *Higher Grade Nickel Zone – 3.0Mt at 0.73% Ni, 0.27% Co, 0.12% Cu*
2. *Low Grade Nickel Zone (3 lenses) – 4.7Mt at 0.4% Ni, 0.12% Co, 0.14% Cu*
3. *Western Nickel Zone – 0.3Mt at 0.8% Ni, 0.78% Co, 0. 1 7% Cu*
4. *Copper Zone – 20–30Mt at 1.0% Cu*

The Kimale deposit is located on the northeastern edge of the Solwezi Dome (Arthurs and Legg, 1974). The deposit was discovered by an airborne radiometric survey, followed by soil sampling, pitting, trenching, induced polarisation, gravity surveys and diamond drilling by New Consolidated Prospecting Company under an agreement with Mwinilunga Mines Limited between 1958 and 1960. The nickel mineralisation occurs in dolomitic limestones and talc schists overlying copper-rich calcareous biotite schists, all of Lower Roan age. A cobalt zone is evident some 500m south east of the copper zone and uranium has also been reported. A copper resource of 1.8Mt at 1.8% Cu and cobalt resource of 1.0Mt at 0.1% Co have been reported but the only data available for the nickel are from one drillhole which intersected 1.2m grading 0.97% Ni. Uranium is also present.

Exploration in the Copperbelt has been concentrated on copper, cobalt and uranium, and nickel anomalies have often been ignored so there is considerable potential for the discovery of further deposits of the Kalumbila and Kimale type. Also, the emphasis on stratabound deposits in the Lower Roan has entailed that other deposits higher in the succession may have been overlooked.

8.2 Lateritic nickel deposits

Nickel in most mafic and ultramafic lavas and intrusions is located in the silicate phases and is uneconomic to extract. Under intense tropical weathering these silicate phases breakdown and the alkalis, alumina and silica are removed, to produce an iron oxide-rich soil or laterite. Nickel tends to remain in the residual laterite and can reach economic grades (~1% Ni). New high pressure leaching technology can extract the Ni and produce a concentrated solution for electrolysis. Such deposits are worked in Cuba and are currently being brought on-stream in Australia, Asia and the Pacific.

Lateritic nickel deposits have not been actively sought in Zambia and, whilst laterite formation has occurred, the number of ultramafic bodies is not large. The Mitaba serpentine has been explored for nickel as described above and soil sampling over the ultramafic layers showed a range from 0.6–1.3% Ni. Grades at Paulwi Hill of 2% Ni are also encouraging. The Munali Hills occurrence has been explored in more detail than the other deposits but the grades and tonnage of the soils and surface gossan are not reported.

8.3 Platinum Group Element deposits

Minor amounts of platinum group elements (PGEs) are recovered from the anode slimes produced during the copper extraction process at the Copperbelt refineries (see also information on platinum in D.R. Congo in Jedwab, 1997). No other economic concentrations have so far been discovered but samples from very few likely prospects have been analysed for these elements. Increased demand for the PGE's for car exhaust catalysts and jewellery has led to an increase in price and a consequent growth in exploration. This, in turn, increased the demand for PGE analysis and reduction in detection limits and cost. New deposit and exploration models have been developed and economic concentrations of PGEs are not necessarily restricted to very large layered intrusions, such as the Bushveld and the Great Dyke, but also occur in a wider range of mafic and ultramafic environments. Hydrothermal transport of PGEs in chloride-rich solutions from sources such as mantle-derived serpentinites can mobilise the metals into a wider range of deposit types.

The Munali Hills nickel prospect has been extensively explored for nickel sulphides and there is some information on the PGE's, which look promising with Pd>Pt, but the grade is only 3.5 g/t in the 3% nickel concentrate. A re-evaluation of the existing data is probably warranted.

9 Minor Metals

9.1 Tin and Tantalum

Historically, tin has only been a minor product of the mining industry in Zambia.The most important area of tin and tantalum production has been the Choma Tin belt in southwestern Zambia (Figure 20), where the deposits have been worked by the local inhabitants and small cooperatives. Other known tin occurrences, of little economic interest, are:

- *Palaeoplacer cassiterite accompanying gold in the lower part of Mporokoso Group clastic sediments at Senga Hill (see Section 4.3) and recent placers derived from them*
- *Pegmatites of the Lundazi area in Eastern Province contain trace amounts of cassiterite and tantalum*
- *Luangwa River placers containing trace cassiterite in the tributaries draining the Petauke–Nchindeni Hills area to the east and south-east and presumably derived from pegmatitic bodies*
- *Mpemba Tin deposits comprising cassiterite in veins and alluvium north of Mkushi (near the eastern end of the Congo Pedicle), and trace amounts of cassiterite (+Nb, Ta, W, Au) in streams to the southwest of Serenje (Banda, 1985)*
- *Trace concentrations of cassiterite in the Pala Darg (Unda Unda) group of tungsten-gold-bismuth occurrences*
- *Tantalite-columbite in Chief Mboroma's area alomg the Lusemfwa River*
- *Cassiterite-quartz veins are associated with greisenized zones of the granites of the Luambwa Dome, 30 km west of Serenje (Watts, Griffis and McOuat, 1991)*
- *Greisen-hosted cassiterite mineralisation and tin-bearing silicate (total 0.17% Sn) in a contact facies of the Hook Granite Complex at Mutumbwe, some 50km north-west of Mumbwa in Central Province (Cikin and Drysdall, 1972).*
- *Cassiterite with malachite and cuprite in a small outcrop and in gravels of the Swishi River near its confluence with the Lalafuta River 120km south- west of Kasempa, North Western Province*
- *Pegmatites and cassiterite-bearing soils at Kauba Hill, Mendham near Mazabuka, and Nega Nega, which represents the extension of the Choma Tin Belt for a further 270km to the north east.*

9.1.1 Choma Tin Belt

The Choma Tin Belt occupies a rugged part of the country parallel to the Mid- Zambezi Rift Valley and forms an 8km wide zone extending about 110km SW–NE (Figure 20). The underlying Muva Supergroup rocks are largely metasedimentary, with an early arkose-carbonate sequence (possibly Ubendian in age), now represented by granulitic gneisses and marbles, and a later argillaceous sequence now comprising schists. The early sequence underwent metamorphism and was intruded by pegmatites and basic igneous bodies, possibly prior to deposition of the argillaceous sediments. F_1 folding of the complete sequence then took place during an early phase of the Irumide orogeny generating north-trending folds, followed by F_2 deformation which produced the dominant north-east trend of fold axes