MANGANESE

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INTRODUCTION

Manganese is a hard, brittle metal, which has a crustal abundance of 0,1 % and, as such, is the twelfth most abundant element. About 90 % of all manganese produced is used in the manufacture of steel, where it is added in the form of ferromanganese and serves as a sulphur fixing agent, a deoxidant and, to a limited extent, as an alloying element (Dancoisne 1994; 1995; Jones 1985; 1991). Manganese binds with sulphur to form a compound with a high melting point, thereby preventing hot rolling defects (Dancoisne 1994), or completely removes the sulphur from the molten metal to the slag (Grohmann 1995). Being more readily oxidised than iron, manganese prevents extreme oxidation of the iron during refining. Manganese in solid solution with iron alters significantly the properties of the resultant steel, making it stronger and tougher. The average manganese content of steel is in the region of 0,7 % (Jones 1985). Specialist manganese steels contain between 10 and 14 % Mn, and are used in wear-resistant applications (e.g. crushing equipment). When present in high concentrations, manganese has the ability to make steel non-magnetic; specialist non-magnetic steels contain some 18 % Mn (Jones 1985). No substitutes exist for the numerous roles manganese plays in the steel industry, and for this reason, manganese is considered a strategic metal by most industrialised nations.

A small amount of manganese, in the form of manganese metal, is also used in the manufacture of non-ferrous alloys, principally aluminium alloys, where it improves corrosion resistance (Jones 1985; Crowson 1994). Manganese is also alloyed with copper to produce a wide range of manganese bronzes (Grohmann 1995). Some 8 % of the manganese produced is used in non-metallurgical applications, principally in dry cell batteries and the chemical industry. The manganese dioxide used in dry cells participates directly in the electrochemical reaction. Manganese also has the ability to exist in six different oxidation states and this property is exploited in the chemical industry. Manganese compounds are used as oxidants (e.g. in the purification of water and acid leaching of certain ores, notably uranium), colourants (e.g. in bricks, ceramics and paints), as well as in fertiliser, animal feed, welding rods and the manufacture of ferrites (Jones 1985; Dancoisne 1995).

Manganese mining in South Africa dates back to the early 1900s when manganese ore was mined at Hout Bay near Cape Town. In 1922 the economic potential of the deposits near Postmasburg in the Northern Cape Province was recognised and production commenced in 1930 after the completion of a rail link. Shortly afterwards the Kalahari Manganese Field (KMF) further north was identified and in 1940 Black Rock Mine was opened. At present the KMF constitutes the principal production area. The more important manganese deposits and occurrences in South Africa are shown in Figure 1 and described in detail later in the Chapter.

Based on available information, South Africa's economically exploitable manganese reserves are in excess of 1 000 Mt. Total world resources of manganese are estimated at ca. 4 900 Mt (these include marginal and presently subeconomic resources), the bulk of which lie in South Africa, the Commonwealth of Independent States (CIS) (former USSR) and Gabon (Grohmann 1995). In the future, manganese may well be obtained from the extensive deposits of manganese nodules on the sea floor, reliable resource estimates of which are not readily available and which have not been included in the global resource figures given above. In 1994, South Africa's production constituted 12,4 % of the world total of 23 Mt, making it the third largest producer after the CIS and China (Grohmann 1995). Almost half of the South African production is exported.

Manganese ores are classified as follows:

metallurgical grade	Mn content 38–55 %
battery and chemical grade	require MnO_2 contents of between 70 and 80 %

The mineralogy of the manganese minerals is complex and their identification is difficult even in the laboratory, because of their fine-grained nature and similarity in hand specimen, and because pure samples of certain minerals are hard to obtain. Numerous manganese-bearing minerals are known but the supergene manganese dioxides, which generally form most of the economic ore deposits throughout the world, are the most important. Of these the psilomelane group of minerals, i.e. psilomelane, cryptomelane, hollandite and coronadite, as well as pyrolusite-polianite, nsutite and wad, or manganiferous earth, are the principal species. Metamorphic and diagenetic manganese minerals, such as the bixbyite and braunite groups, and hausmannite and jacobsite, are the principal ore types in the deposits of the Postmasburg and Kalahari Fields. The manganese silicate, rhodonite, and the carbonate, rhodochrosite, are also important in some parts of the world. Diagenetic minerals are generally processed to chemical or battery grade while the metamorphic minerals are commonly used for metallurgical applications.

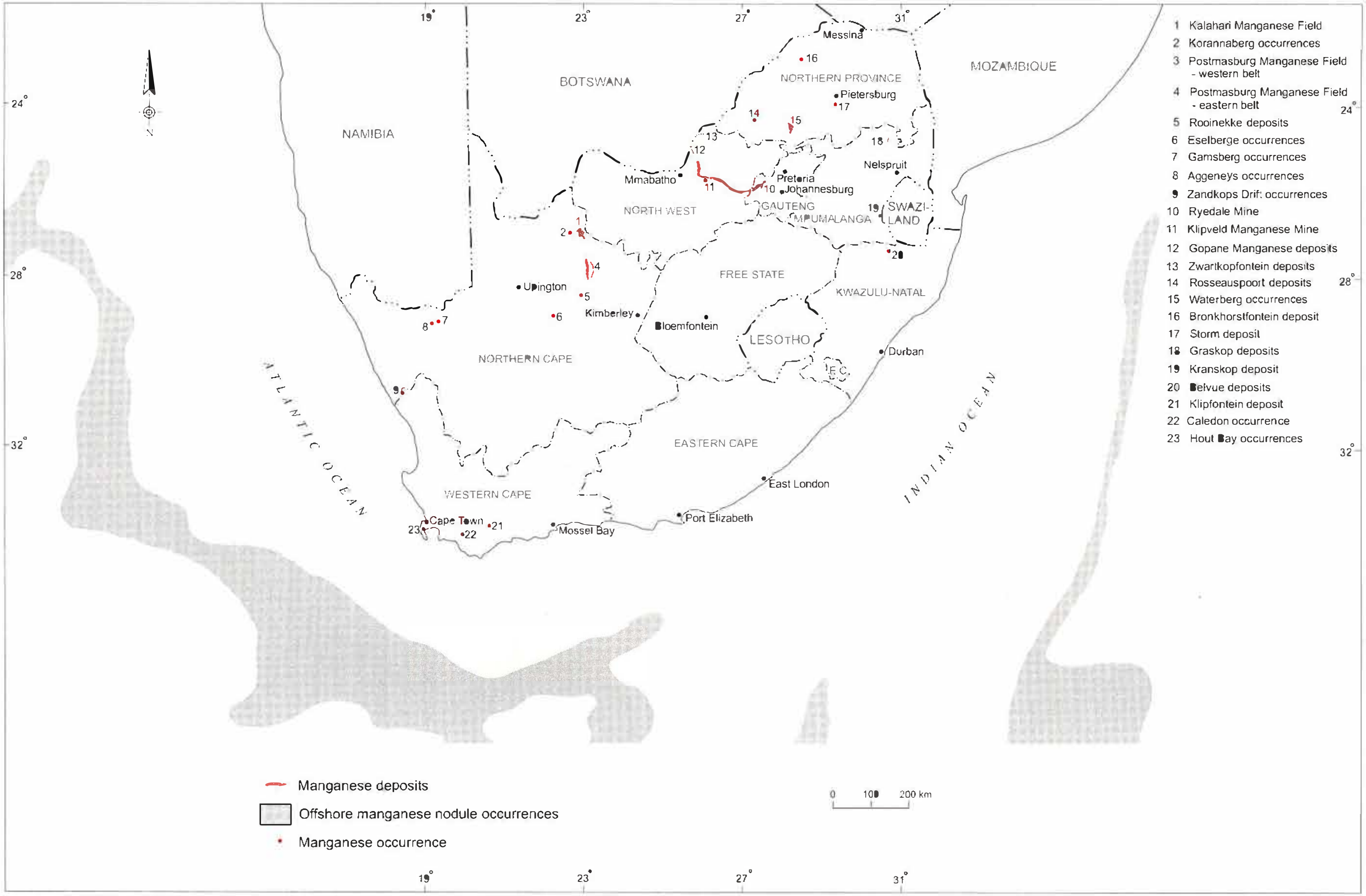

Fig. 1 – Locations of manganese deposits in South Africa.

CLASSIFICATION AND GENESIS OF MANGANESE DEPOSITS

Manganese deposits can be classified into three major categories (Roy 1981; 1992), namely hydrothermal, sedimentary and supergene. Hydrothermal deposits are usually of minor economic importance. Sedimentary deposits form the most important type and carry the largest reserves worldwide. They occur throughout the geological record and can be further classified into volcanogenic and non-volcanogenic deposits. The former are generally small in size and occur in volcano-sedimentary sequences of primarily Phanerozoic age, whereas the latter are found in clastic, carbonate or iron-formation-dominated sequences of various ages. Manganese deposits in modern-day basins may fall into either of the above subtypes. Supergene manganese ores form under surficial weathering conditions when in situ concentration of manganese takes place at the expense of manganiferous 'protores' (i.e. Mn-bearing parent lithologies of largely carbonate composition). Metamorphic processes may frequently modify the above deposit types, sometimes resulting in higher-grade ores.

South African manganese deposits are essentially confined to the Early Proterozoic Transvaal Supergroup, Northern Cape Province. They can be grouped into two major categories: 1) karst-fill type (i.e. residual Fe-rich manganese ores developed in dolomites of the Campbell Rand Subgroup) in the Postmasburg Fe-Mn Field and 2) syngenetic (i.e. carbonate-rich manganese deposits interbedded with banded iron formations (BIFs) of the Voëlwater Subgroup) as in the KMF.

DEPOSITS AND OCCURRENCES

NORTHERN CAPE PROVINCE

Transvaal Supergroup
(Previously Griqualand West Supergroup)

Kalahari Manganese Field (KMF)

The KMF lies northwest of Kuruman and consists of five structurally preserved erosional relics of the Hotazel Formation, which comprises Superior-type iron formation with interbedded units of manganese ore. The Mamatwan–Wessels basin (or main Kalahari deposit) is the largest of the five deposits, comprising a basin with a strike length of 41 km and width varying between 5 and 20 km (Fig. 2). The total area underlain by the basin is about 425 km^2 (Miyano and Beukes 1987). Of the other four deposits, the Hotazel and Langdon Annex deposits, which lie east of the main deposit, have been virtually mined out. The Avontuur and Leinster deposits lying north of the main deposit are small and of subeconomic grade. Almost the entire manganese field is covered by the Kalahari Formation, the only outcrop being at Black Rock, where the Hotazel Formation forms a small koppie. In the southeastern portion of the basin, the Hotazel Formation is near surface and is directly overlain by the Kalahari Formation. However, in the central and northern parts of the basin, the Hotazel Formation is separated from the Kalahari Formation by the Mooidraai Formation, lithologies of the Olifantshoek Supergroup and/or the Dwyka Formation of the Karoo Supergroup (Figs 3 and 4).

The Hotazel Formation forms part of the Voëlwater Subgroup, which constitutes the uppermost portion of the Transvaal Supergroup. In the KMF, the Hotazel Formation is underlain by lava of the Ongeluk Formation and in places is overlain by dolomite and chert of the Mooidraai Formation (Miyano and Beukes 1987; Griqualand West Working Group of SACS, pers. commun.). The detailed stratigraphy of the Hotazel Formation comprises banded iron formation interbedded with three manganese-rich horizons, termed the upper, middle and lower manganese bodies (Fig. 3). The lower body varies in thickness from 5--45 m and represents the main ore bed. The middle body is only 1–3 m thick and thus subeconomic. The average thickness of the upper body is 5 m and limited exploitation of this unit has taken place (Miyano and Beukes 1987). In the southern portion of the KMF, however, the upper body may reach 30 m in thickness and the middle body is often absent. The amount of the sequence preserved in any area is related to the severity of palaeoerosion.

The lower manganese body is characterised by a braunite-kutnahorite mineral assemblage and is considered to represent a primary to early diagenetic sediment. This is referred to as Mamatwan-type ore and represents approximately 97 % of the total manganese resource of the Kalahari deposit (Miyano and Beukes 1987). Along the northwestern margin of the area, intense faulting, thrusting and associated hydrothermal activity have removed carbonates and silica, thereby upgrading the ore to a coarse-grained braunite II-hausmannite-bixbyite assemblage, known as Wessels-type ore (Miyano and Beukes 1987; Gutzmer and Beukes 1995). The transition from Mamatwan- to Wessels-type ore is not well constrained. Local thrusting has duplicated the ore horizon in places, as is the case at Wessels and Black Rock. The Hotazel and Langdon Annex deposits represent portions of the Hotazel Formation that have been downfaulted into graben structures. Here, hydrothermal and supergene enrichment have produced an ore with a manganese content in excess of 60 %, often referred to as Hotazel supergrade ore (Miyano and Beukes 1987). The Avontuur and Leinster deposits contain a low-grade jacobsitic type of ore.

The principal contaminants in Mamatwan-type ore are calcium and magnesium carbonates, which fortunately impart desirable (self-fluxing) properties to the ore. This ore has a relatively low combined Fe and Mn content of 40--44 %, the average ore produced at the Mamatwan Mine having 38 % Mn and 4,3 % Fe. The Wessels and Hotazel ore types are of a higher grade, having a combined metal content of 58--68 %, with Mn varying from 44--65 % and Fe from 6–18 %. Phosphorus is very low and silica is generally not high. These ores are frequently bought to blend with ores high in phosphorus from other sources.

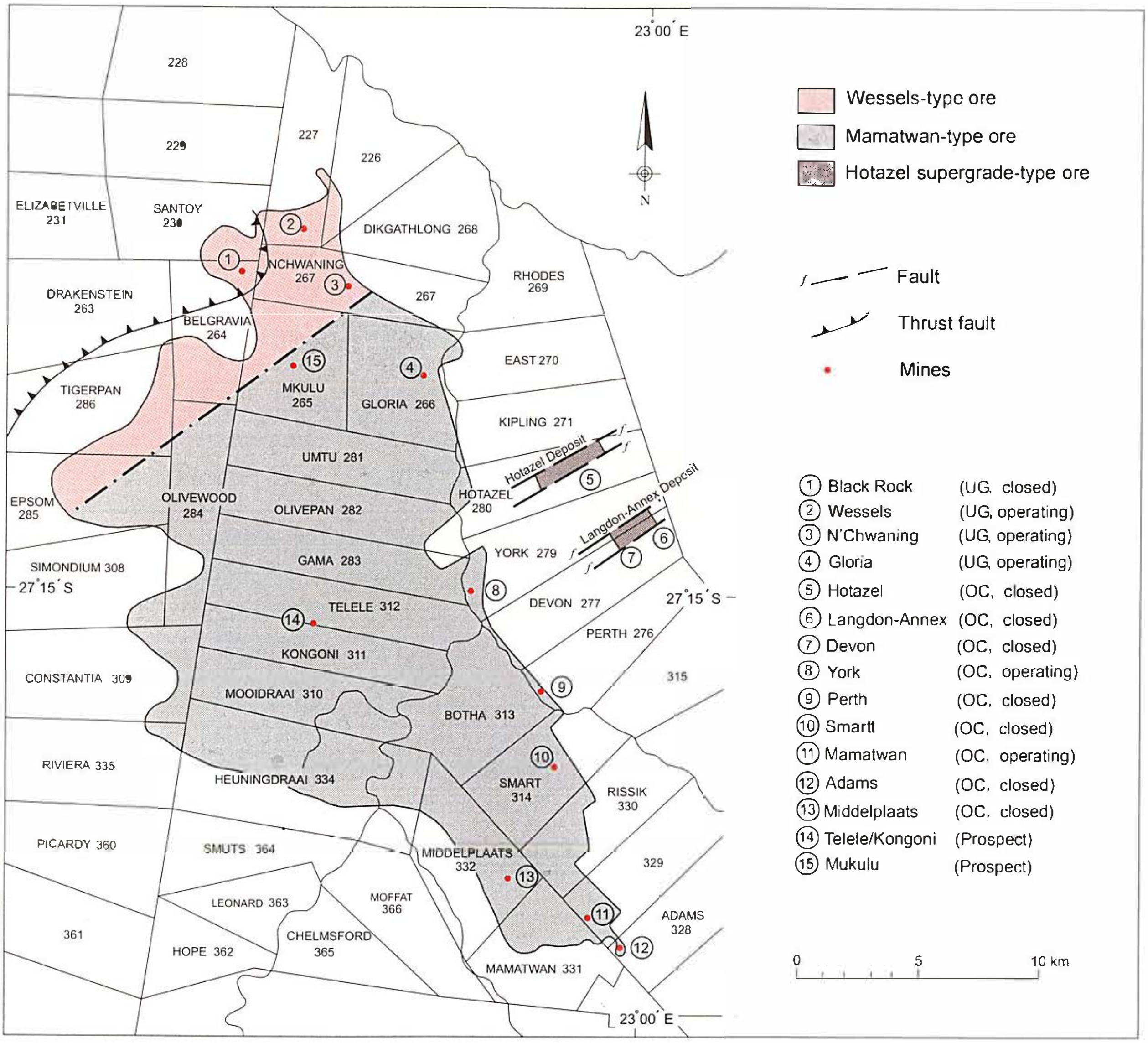

Fig. 2 – Outline of the Kalahari Manganese Field showing the distribution of ore types and position of the more significant deposits (information provided by SAMANCOR).

In the central parts of the Kalahari basin a reserve of several billion tonnes is indicated, but saleable grades would be considerably less. The depth of cover, in excess of 900 m in places, also renders a major part of the low-grade ores unmineable at present.

The manganese ore bodies of the KMF have been exploited at numerous localities. Several mines that are now abandoned and those currently producing are listed in Table 1, with locations shown in Figure 2.

The genesis of the manganese deposits of the KMF remains unresolved and genetic models proposed to date fall into three groups, namely volcanogenic, chemical sedimentary and epigenetic. Volcanogenic models involve the introduction of Mn, Fe and other elements from a submarine volcanic source and require extensive precipitation of highly fractionated metalliferous sediments by means of superimposed sedimentary cycles (Beukes *et al.* 1982; Beukes 1983; Kleyenstüber 1984; Nel *et al.* 1986). Recently Cornell and Schütte (1995) suggested that the influence of sedimentary processes is not of major importance and a volcanogenic-exhalative mechanism is favoured. Beukes and Gutzmer (1996) have strongly disputed a volcanic-exhalative origin for the Mn. The sedimentary model places emphasis on the chemical-sedimentary processes pertaining to the deposition of the Hotazel Formation, regardless of the source of Fe and Mn (Tsikos and Moore, in press). The epigenetic model (De Villiers 1992), suggests that all mineralisation occurred during a younger hypogene hydrothermal event, but this model has been strongly disputed (Beukes 1992).

Postmasburg Manganese Field (PMF)

The PMF extends northwards from Postmasburg for about 65 km to Sishen and may be divided into a Western and an Eastern belt. Both belts lie on the Maremane Dome, which consists predominantly of

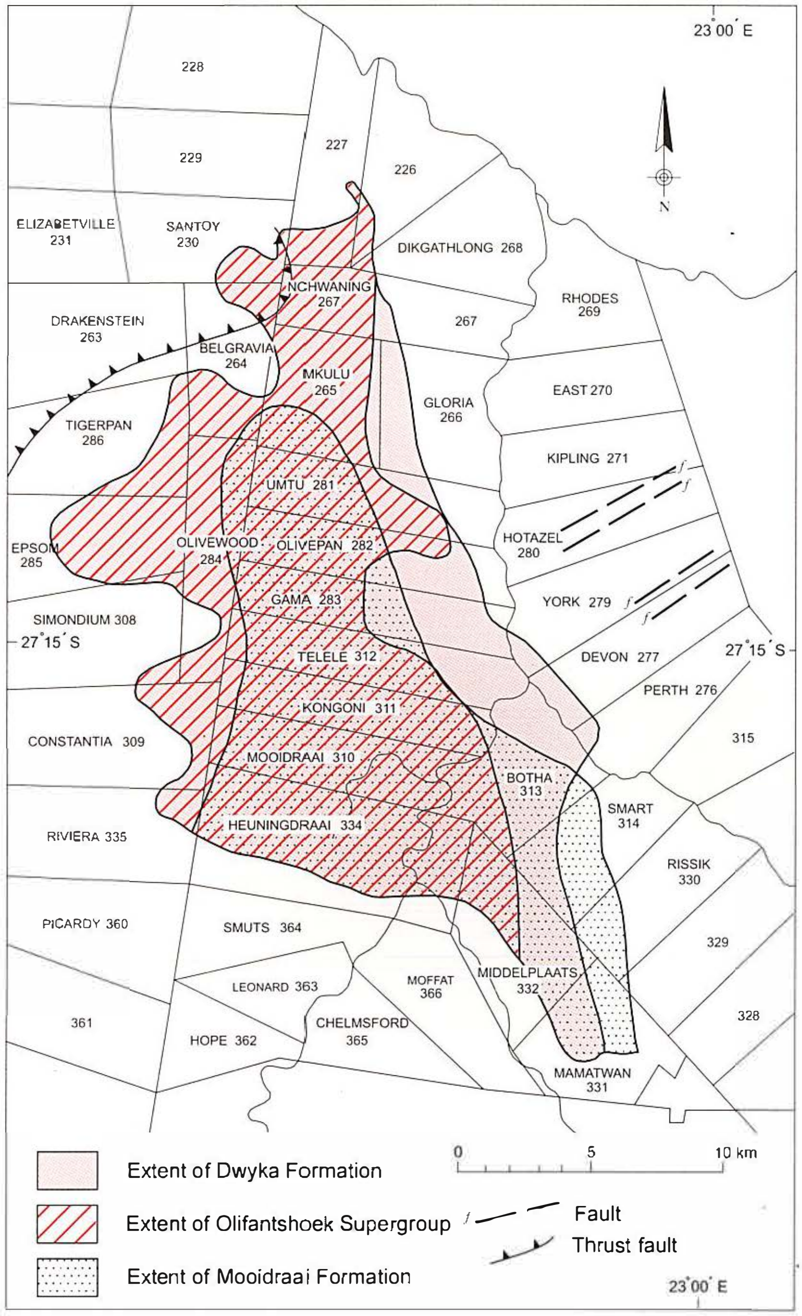

Fig. 3 – Simplified suboutcrop map of the Dwyka Formation, Mooidraai Formation and Olifantshoek Supergroup lithologies in the Kalahari Manganese Field (information supplied by S. van der Merwe of SAMANCOR).

carbonate rocks of the Campbell Rand Subgroup (Transvaal Supergroup). The Western belt extends northwards from Beeshoek to Sishen while the Eastern belt, which runs from the same two points, is more arcuate in form (see Fig. 1 in the Chapter on iron). The manganese deposits are related to the unconformity between the Campbell Rand Subgroup and the Gamagara Formation (Olifantshoek Supergroup) which locally overlies it. In the centre of the dome, where the Gamagara Formation rests on the manganese-rich Reivilo Formation of the Campbell Rand Subgroup, supergene manganese deposits are developed in the Sishen Formation of the Gamagara Formation (Grobelaar and Beukes 1986). Prior to the deposition of the Gamagara Formation, periods of erosion resulted in the formation of a karst terrain with palaeosinkholes. Iron formation of the Asbestos Hills Subgroup and chert from within the carbonate lithologies slumped into the sinkholes to form the Manganore iron formation and Wolhaarkop breccia respectively. Manganese-rich ooze also accumulated in solution cavities and through subsequent burial and low-grade metamorphism was transformed into massive ore.

Table 1 – ***MINES (OPERATING AND CLOSED) AND PROSPECTS OF THE KALAHARI MANGANESE FIELD***

MINE	STATUS	ORE BODIES AND ECONOMIC WIDTHS	ORE TYPE	RESERVES	COMPANY
Mamatwan	Operating	Lower; 19 m	Mamatwan	400 Mt > 35 % Mn	Samancor
Gloria	Operating	Lower; 10 m	Mamatwan	21 Mt > 40 % Mn	AssMang
York	Operating	Lower; unknown	Mamatwan	Limited	Nat. Mn
N'Chwaning	Operating	Lower; 6 m Upper; locally exploited	Wessels	200 Mt > 40 % Mn	AssMang
Wessels	Operating	Lower; av. 4,5 m Upper; locally exploited	Wessels	ca. 70 Mt	Samancor
Telele/Kongoni	Prospect	Lower	Mamatwan	under evaluation	AssMang
Smartt	Closed, 1962 Prospect	Lower	Mamatwan	under evaluation	Samancor
Mukulu	Prospect		Wessels	43 Mt > 40 % Mn	AssMang
Middelplaats	Care and Maintenance	Lower; 5 → 10 m	Mamatwan	85 Mt > 35 % Mn	Samancor
Adams	Closed, 1992	Lower	Mamatwan		Nat. Mn
Perth	Closed, 1979	Lower	Mamatwan	1,6 Mt > 40 % Mn	AssMang
Devon	Closed	Lower	Mamatwan	Small	AssMang
Black Rock	Closed, 1992	Lower; 6 m Upper; locally exploited	Wessels	45 Mt > 40 % Mn	AssMang
Hotazel	Closed, 1990	Upper; 6 m Lower; av. 15 m	Hotazel Supergrade	20 Mt > 48 % Mn	Samancor
Langdon Annex	Closed, 1992	Lower	Hotazel Supergrade		Nat. Mn

Information in this table is from correspondence with Associated Manganese (Anglovaal) and Samancor (Gencor) as well as Nel *et al.* (1986) and Jennings (1986). Note the reserves column also refers to ore already extracted.

The mineral assemblage, braunite and bixbyite, reflects low- to medium-grade metamorphism. Recent surface processes resulted in the addition of tetravalent Mn oxides of the psilomelane group to the assemblage (Von Plehwe-Leisen and Klemm 1995).

Due to a decrease in grade with time, adverse mining conditions and the gradual fall in demand for siliceous manganese ore of the type that occurs in the Eastern belt, production in this area was curtailed in the 1960s in favour of the Western belt. Mining in the Western belt has now also ceased in favour of the KMF.

The Western belt is characterised by ore that formed in two ways, viz. as replacement bodies in shale of the Gamagara Formation, and as bodies of ore in material that slumped deeply into the underlying dolomitic lithologies. The replacement ore is typically ferruginous, consisting essentially of hard, coarsely crystalline bixbyite with which manganese diaspore and micaceous ephesite may be associated. Ore in the karst pockets and solution channels consists mainly of braunite with some hausmannite and jacobsite (De Villiers 1960; Von Plehwe-Leisen and Klemm 1995). Mining in the Western belt was focused around Lohatlha on the farms Bishop 671, Lo-

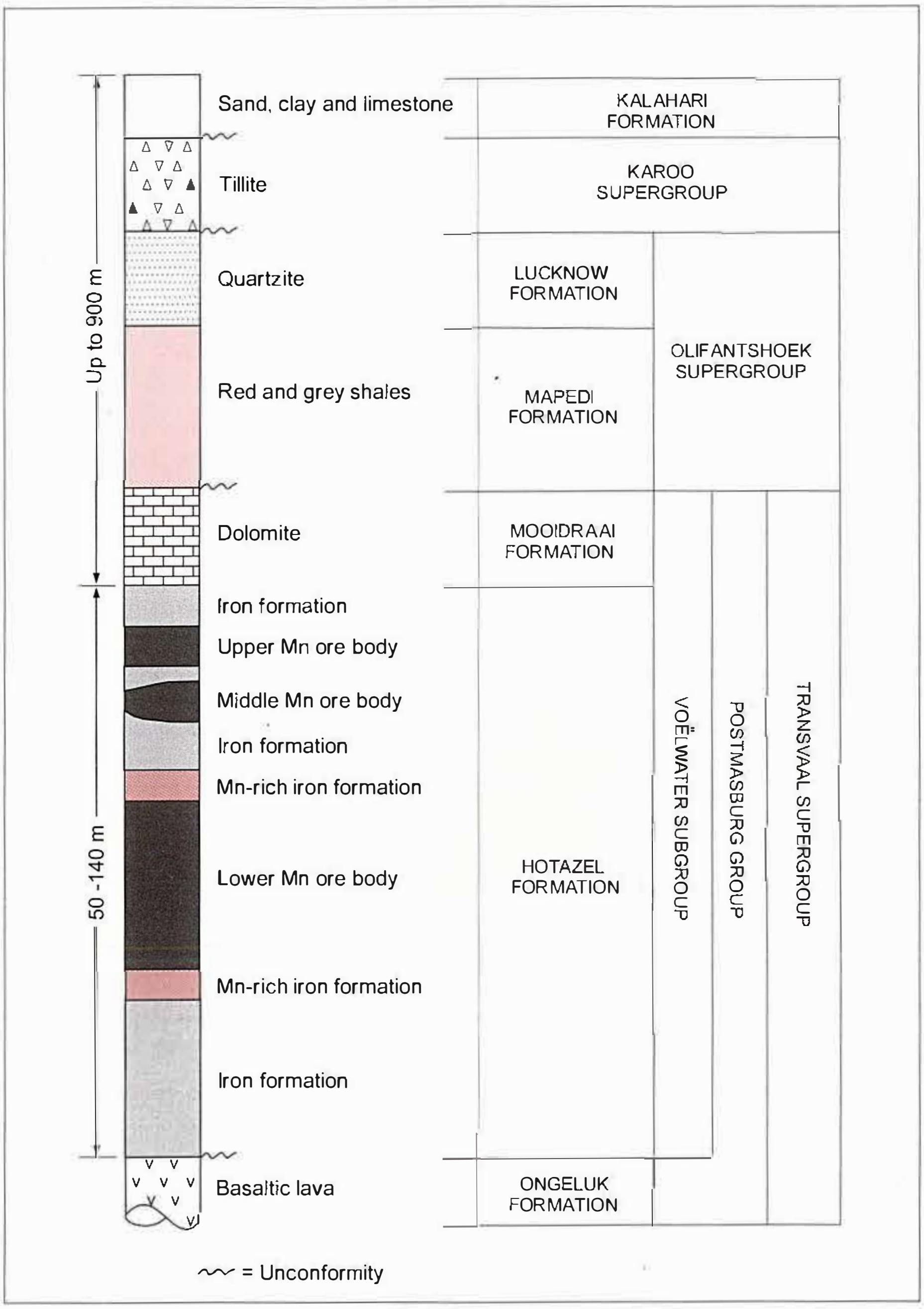

Fig. 4 – Generalised stratigraphic column for the KMF (modified from Cornell and Schutte 1995).

hatlha 673, Gloucester 674, Paling 434, Lomoteng 669, Magoloring 668 and Doorn Fontein 446.

The Eastern belt forms an arc of breccia hills, the so-called Klipfontein Hills. The deposits of the Eastern belt are characterised by their intricate shapes, inconsistent sizes and their association with both the siliceous Wolhaarkop Breccia and consolidated slump material and wad, in steep irregular karst structures. Braunite is the most common ore mineral (Von Plehwe-Leisen and Klemm 1995). On the farm Kapstewel 436 near Manganore, a siliceous manganese ore is being extracted from numerous surface workings. This small operation, known as Kapstewel Enterprises, is owned by Union Mines and has operated intermittently over the past three years.

The manganese ore of the PMF is hard and tough and stands up very well to transport with the production of a minimum of fines. Chemically the ore conforms to metallurgical requirements, the manganese content varying from 25 to 50 %. In the case of the ferruginous ore of the Western belt, the ratio of manganese to iron is usually between 3:2 and 4:1, but in the case of the siliceous ore of the Eastern belt, it is 10:1 and higher. Phosphorus is usually less than 0,05 %, aluminium levels are acceptable and small quantities of barites are generally present. As most of the high-grade ore and significant amounts of the lower-grade ore have been mined out, production has virtually ceased. Ore-reserve calculations cannot be attempted because of the irregular shape of ore bodies, but it is estimated that a few million tonnes of low-grade ore remains. Deposits of this type are currently only of minor economic importance.

Other Deposits of the Transvaal Supergroup

In the area around Aucampsrus ores are found similar to those of the Eastern and Western belts of the PMF. Mining has taken place on farm no. 477, south of Aucampsrus.

In the vicinity of Rooinekke, 70 km southwest of Postmasburg, low-grade supergene manganese deposits occur at various horizons in banded iron formation and flagstones near the top of the Koegas Formation. Several small lenticular deposits have been opened up on a number of farms stretching from Waterkloof 95 in the north to Cairn Top 188 in the south. The ore is of a low grade, the Mn content being about 35 %, with Fe ranging from 25–27 %.

In the Korannaberg, some 30 km due west of Hotazel, the banded iron formation of the Hotazel Formation is again exposed through folding and faulting. Low-grade manganese ore occurs in fault breccias on the farms Groenwater 304, Blaauwkrantz 342 and Nelskop 292. A borehole on Blaauwkrantz penetrated more than one horizon containing 5 to 6 % Mn in a hard siliceous mass within banded iron formation.

Bushmanland Group

Manganiferous iron ore occurs near Gamsberg on portion 1 of the farm Gams 60, some 40 km southwest of Pofadder (see Chapter on iron). The ore occurs in metamorphosed sediments of the Nab Subgroup and the principal ore minerals are haematite, jacobsite, cryptomelane, bixbyite, pyrolusite and psilomelane. The ore has up to 26 % Mn and is exposed intermittently over a strike length of 8 km, with thicknesses of up to 3,7 m. Similar deposits have been found on Zuurwater 62, Koeris 54 and Aggeneys 56, west of Pofadder. These deposits occur in the Bushmanland Group and are genetically related to the nearby base-metal deposits (see Chapters on copper, lead and zinc).

On Zandkops Drift 537, south of Garies in the Namaqualand District, ferruginous manganese ore occurs in eastward-trending veins and lenses within a broad shear zone within granite gneiss. Grades may reach 35 % Mn, but reserves are limited (De Villiers 1960).

Olifantshoek Supergroup

In the Eselberge about 30 km north of Marydale, pockets and veins of pyrolusite and psilomelane occur both along the brecciated contact of Matsap Subgroup sediments and underlying lava of the Boegoeberg Dam Formation and in the shale, quartzite and dolomite of the Transvaal Supergroup. About 200 t of ore were reputedly produced in 1960 on the farms Marais Draai 4 and Zeekoebar 9.

GAUTENG, NORTH WEST, NORTHERN AND MPUMALANGA PROVINCES

Chuniespoort Group, Transvaal Supergroup

There are several occurrences of crystalline manganese ore and manganiferous earth or wad in the region west and northwest of Krugersdorp. These occurrences are the result of weathering of the Mn-rich dolomites and the subsequent accumulation of residual Mn-rich material. Soil colour above Mn-rich zones is chocolate brown whereas that which develops above dolomite devoid of manganese is a reddish colour. Most of the manganese in these types of deposits occurs as the MnO_2 minerals nsutite, pyrolusite and psilomelane. Grades are generally between 10 and 40 % MnO_2. In an unrefined form this material is used in the extraction of uranium, while beneficiation may yield a product with MnO_2 in excess of 80 %, which is suitable for the chemical industry. Metorex (Pty) Ltd is presently mining manganese ore from opencast mines on the farms Ryedale 75 IQ, Luipardsvlei 243 IQ, Elandsfontein 277 IQ and Brandvlei 261 IQ. The Ryedale deposit has been investigated by Gutzmer and Beukes (in prep.) who found that the deposit is not a residual deposit formed by the weathering of Transvaal dolomites as was claimed by De Villiers (1960). The earthy Fe-Mn ore horizon, which is up to 15 m thick, occurs within sandstone and clay-rich beds which are of Karoo age. The exact origin of the deposit is still unknown although it is likely that the concentration of iron and manganese took place during the deposition of Karoo strata in a lacustrine environment which developed above karstic depressions in the dolomite. Dissolution of the dolomite might have contributed iron and manganese to the lacustrine environment. Further to the northwest (in the North West Province), scattered deposits are present in the upper portions of the Chuniespoort Group, from the farm Rietpan 479 JP through the Zeerust lead-zinc-fluorite field, to the Botswana border. Many of these occurrences have been exploited on a small scale in the past (Hammerbeck and Taljaardt 1976). At present the Klipveld Manganese Mine is working the deposits on the farms Klipkuil 352 JP and Ruigtelaagte 353 JP in the Lichtenburg District. On these farms, several separate bodies of MnO_2 are present in palaeosinkhole structures within the Lyttelton Formation. In the Marico District, manganese was once mined to a limited extent on the farms Genadendal 116 KP and Lisbon 242 KP. At the Thabazimbi Iron Ore Mine, large masses of wad and at least three bodies of crystalline manganese ore, assaying up to 57 % Mn, are located within dolomite, immediately below the haematite ore bodies, where much subsurface weathering and dissolution has taken place. The ore is of good quality, but mining presents serious difficulties because of the treacherous nature of the ground. Disseminations of pyrolusite are known to occur over a large area of decomposed dolomite in very inaccessible country on top of the Rosseauspoort Range on Rosseauspoort 319 KQ, 5 km northwest of Thabazimbi.

On Storm 370 KS, about 50 km south of Pietersburg in the Northern Province, a manganese deposit is present in the upper portions of the Chuniespoort Group. Narrow bands and encrustations of pyrolusite- and psilomelane-type ore are confined to a few zones of up to 1 m wide in a body of chert breccia. Both the Mn mineralisation and the chert breccia are the result of residual accumulation after selective dissolution of the dolomite. In the early 1970s two occurrences were investigated by Foskor; they proved near-surface ore reserves in the region of 50 000 t with an average grade below 30 % MnO_2. More recent investigations by Nolmag claim proven reserves of 4 Mt with a Mn content of 6 %. A more reliable estimate is about 1 Mt proved ore reserves with the possibility of further deposits along strike (R. Burnett, pers. commun.). At present the deposit is being worked on a trial basis under the name Majestic Manganese.

Extensive deposits of manganiferous earth are found in dolomite along the Drakensberg Escarpment in Mpumalanga, the best known being that on the farm Graskop 564 KT. Recent investigation of these deposits revealed a potential resource of 13 Mt averaging 14 % MnO_2, which could be exploited using opencast mining techniques (Tennick 1991). Exploitation of the deposits could prove difficult due to the water-saturated nature of the ore, irregular shape of the ore bodies and environmentally sensitive location. Nevertheless, in mid-1997 a processing plant was set up at the nearby Golden Jubilee Mine to process the manganese, and the same company Samroc started excavating an open pit. A similar type of occurrence has also been reported on Driekop 546 KT.

Manganiferous earth yielding good-quality umber occurs on Diepgezet 434 JT, 32 km northeast of Carolina, in the Province of Mpumalanga (De Villiers 1960).

Pretoria Group, Transvaal Supergroup

The Gopane manganese deposit lies 56 km northwest of Zeerust in the North West Province, near the Botswana border. The ore body averages 0,8 m in thickness and mineralisation is confined to a 1- to 7-m-thick zone in a stromatolitic limestone bed which forms part of the Polo Ground Member of the Rooihoogte Formation. The ore body is conformable with the sediments and mineralisation is known to extend along strike, both to the northwest and southeast. From Skilpadhek on the Botswana border, the mineralised horizon extends some 15 km southeast into South Africa and a further 25 km northwest into Botswana. The dip of the sediments averages 15° to the northeast and at Gopane mineralisation has been shown to extend 124 m down dip. The ore is ferruginous and siliceous in character, containing goethite, quartz, various phyllosilicates and the manganese minerals nsutite, pyrolusite and cryptomelane, in intimate association. The manganese content varies between 15 and 80 % MnO_2. When the mine closed in 1980, 0,8 Mt of saleable material had been produced. The genesis of this deposit probably involved dissolution of dolomite and the residual accumulation of manganese (Steyn *et al.* 1986). Some 40 km further north manganese occurs in the same stratigraphic horizon from the farm Zwartkopfontein 7 KO, on the Botswana border, eastward to Lekkerdorst 104 KP, a distance of about 20 km. Here the manganese is present in brecciated Polo Ground quartzite, with the best mineralisation occurring in the most intensely deformed portions, such as on Secheli's Oude Stad 6 KO. No analysis of the ore is available. However, on the Botswana side of the border, nsutite was mined from a similar deposit.

On Rooisloot 142 JQ, in the Crocodile River Fragment, manganese ore occurs as a massive infilling in a gash vein in quartzite of the Timeball Hill Formation. The amount of ore available appears to be very limited (De Villiers 1960).

Manganese ore consisting essentially of braunite and polianite was mined from a mineralised fault zone in Magaliesberg quartzite on the farm Derdepoort 326 JR northeast of Pretoria, but the deposit was exhausted.

Waterberg Supergroup

Manganese ores occurring as gash-vein fillings, fault and shear zone impregnations and localised concentrations in red and purple sandstones are present at numerous localities in the Waterberg. Invariably these deposits are either small or of poor quality and even small-scale mining is not economic. Most of the occurrences which attracted attention are located in the triangle between Warmbad, Nylstroom and Loubad Siding (Hammerbeck and Taljaardt 1976).

A deposit of possibly 10 to 15 Mt of low-grade ore is present in an outlier of Waterberg sediments on the farms Bronkhorstfontein 42 LR and Baden 90 LR, 130 km northwest of Pietersburg. Up to three ore horizons are developed, all of which are in excess of 1 m thick and have Mn contents ranging between 30 and 40 % (Hammerbeck and Taljaardt 1976). The deposit has been exploited in the past, but mining ceased in 1966, due to the remoteness of the deposit. A renewed investigation of these deposits was being undertaken during 1997. A relatively large manganese occurrence is present on Kilpspruit 457 KQ 40 km east-northeast of Thabazimbi. Analyses reveal MnO concentrations of up to 26,5 %, as well as high Ba, W, Cu and Zn values (Callaghan 1993).

MPUMALANGA AND KWAZULU-NATAL PROVINCES

Pongola Supergroup

Secondary enrichment of manganese oxides in banded iron formation has been recorded from various localities in rocks of the Mozaan Group. South of Amsterdam, enrichment is structurally controlled, the best mineralisation occurring on Kranskop 422 IT, where about 100 t of ore were extracted in the 1950s. Chemical analyses reveal an MnO_2 content of between 3 and 7 % with the main ore minerals being cryptomelane, nsutite and pyrolusite (Hammerbeck 1982). Similar superficially enriched manganese occurrences are known in the Vryheid–Paulpietersburg area, the most significant being on Belvue 600, 40 km northeast of Vryheid (De Villiers 1960).

WESTERN CAPE PROVINCE

Cape Supergroup

Manganese ores, usually pyrolusite and psilomelane, are found as veins and impregnations in quartzite and sandstone of the Table Mountain Group in the western and southwestern portions of the Province. In many instances the ore is of a very high grade, although the phosphorus content tends to be high. The deposits are the result of percolating ground waters leaching Mn from the sandstone lithologies and precipitating it in shallow fissures (Marchant *et al.* 1978). It appears the best material was formed in open veins, whereas replacement ore, bordering the veins, is much poorer. All the deposits are small, seldom persist in depth and are at present subeconomic.

Several localities have been worked in the past, the most famous being the deposits at Hout Bay. For further details on other small deposits and occurrences see Hammerbeck and Taljaardt (1976) and De Villiers (1960).

Manganiferous and ferruginous material has been deposited by the chalybeate springs near Caledon. The springs are situated on the faulted contact between the Table Mountain Group and the Bokkeveld Group.

The Klipfontein manganese deposit on the farm Kleinfontein 367, 22 km west-southwest of Swellendam, consists of a vein associated with a fault in the sandstone-rich Rietvlei Formation and was mined during the 1970s (Hammerbeck and Taljaard 1976; Malan *et al.* 1994).

OFFSHORE DEPOSITS

Manganese nodules have been recorded off both the east and west coasts of southern Africa. The occurrences are all subeconomic, with the best prospects lying off the Namaqualand and Namibian coasts (Rogers 1995).

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