Gold

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1. Introduction

1.1 History

The first gold discovery in Namibia was made during early German colonial times (1850s) in the Sinclair Sequence, Rehoboth District. Production was negligible up to 1899, after which mining was very limited. A highly speculative pegging boom took place on the Rehoboth gold fields during 1933 and 1934, and subsequently up to 1941, 199.2 kg of gold was produced from small oxidised and supergene-enriched deposits.

The 1917 discovery of the Ondundu gold fields in the Omaruru District marked the first, and only, true Namibian “gold rush”. Mining of primarily alluvial/eluvial deposits and some hard-rock mining produced 614.4 kg of gold until closure in 1963.

During the period 1937 to 1943, alluvial gravels were worked in the Epako–Otjua area, Omaruru District, producing some 46.9 kg gold.

The commissioning and coming into production of the Navachab Gold Mine in the Karibib District in 1989 was a result of the more recent upswing in gold exploration that started in the early 1980s and continues today. The current production of some 2000 kg gold from 1.3 million t of ore per year dwarfs all previous production.

Up to the 1960s, approximately 662 kg of gold was produced from several small mines. Between 1965 and 1989 an additional 1878 kg of gold was produced, mostly as by-product from base metal mines. Since 1989, an additional 16 546 kg (up to 1997) has been produced, primarily from Navachab.

1.2 Geological Setting

Until the discovery of the gold-skarn deposit at Navachab, the only known primary gold mineralisation in Namibia was of the quartz-vein type, with limited secondary development of alluvial/eluvial deposits.

Hydrothermal gold quartz veins with associated base metals occur at several localities within the Huab Complex and Khoabendus Group in the northwest of Namibia. In the geologically similar volcano-sedimentary Sinclair and Rehoboth Sequences, supergene enrichment through oxidation of auriferous hydrothermal sulphides has provided grades sufficient to support small-scale mining ventures.

The hydrothermal Ondundu gold deposits are Namibia’s prime example of disseminated gold mineralisation development with tourmalinisation, followed by enrichmnt within structurally controlled quartz vein systems.

The marble-hosted gold-skarn at Navachab is related to multistage mineralisation in the Central Zone of the Damara Sequence.

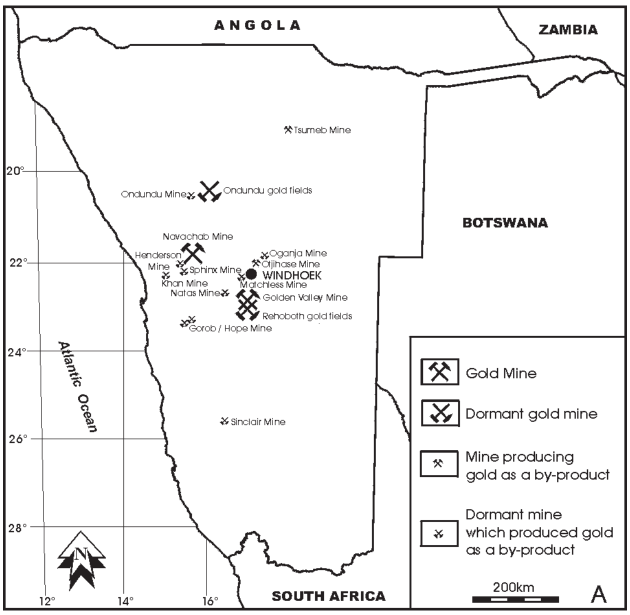

Figure 1: Locality map of the Namibian gold fields

These two principal styles of gold mineralisation are not the only types present in Namibia. Amongst others, Nosib Group quartzites east of Sesfontein and near Opuwo contain gold-bearing quartz veins, while Swakop Group rocks host auriferous pegmatites. In addition, several types of base metal mineralisation carry gold that can be extracted as a by-product. Otjihase, Tsumeb and Kombat mines are examples of such base metal orebodies (see Fig. 1).

2. Gold Occurences in Pre-Damaran Rocks

2.1 Abbabis Metamorphic Complex

2.1.1 Naob Formation

2.1.1.1 Ubib Mine, Ubib 76/Naob 69

The Ubib Mine is situated on the boundary of the farms Ubib 76 and Naob 69, 17 km south of Usakos, on the southern limb of the Chuos syncline. Patchy disseminated copper mineralisation, primarily chalcopyrite and bornite, occurs on the contact between minor discontinuous quartzite and anthophyllite schist over a strike length of 1000 m and up to 1.5 m in width. Although Scott (1976) does not mention gold in his ore reserve calculations, grab-sampling of the old prospect workings by Catterall and Land (1988) gave assay results ranging between 0.5 and 2.6 g/t gold.

2.1.2 Undifferentiated

2.1.2.1 Henderson Mine, Naob 69

The abandoned copper mine on Naob 69, 13 km southwest of Usakos, was initially developed prior to 1914 with two vertical and two inclined shafts. Copper mineralisation on the contact between Abbabis granitic gneiss and biotite-amphibolite schist/calc-silicate rock footwall and Nosib quartzite has been mined to a depth of about 70 m (Anon, 1967). The 4-m-wide mineralisation zone outcrops as malachite-stained quartz gossan that strikes east for some 350 m, dipping at 45^{o} to 60^{o} to the south, and frequently interrupted by pegmatite bodies. The easternmost 250 m has been proved to be auriferous (Smith, 1965). In the old workings, mineralisation occurs within sahlite (calcium clinopyroxene)-bearing brecciated aplite situated in tourmaline-hornblende schist and calc-silicate rocks (Catterall and Land, 1988). Native gold is associated with bornite and chalcopyrite (Brinkman, 1924; Smith, 1965). Although Scott (1976) has also reported gold mineralisation, he does not include gold in his ore reserve calculations. Channel-sampling assays reported by Catterall and Land (1988) ranged between 70 and 1685 ppb gold and a grab sample contained 2.4 g/t gold.

2.1.2.2 Anderson Mine, Naob 69

The name is an alterntive to "Henderson" (see 2.1.2.2 above). Scott (1976) reported a chalcocite-/malachite-bearing quartz vein containing visible gold. Grab samples taken by Badenhorst (1992) contained 1.05 g/t and 4.47 g/t gold.

2.1.2.3 Occurrences

On Abbabis 70, 15 km southeast of Usakos, gossanous quartz-magnetite veins on the edge of a mafic dyke yielded a maximum value of 1.0 g/t gold (Smith, 1965; Steven, 1994; Steven *et al*., 1994).

Stream-sediment sampling on Narubis 67, 5 km southeast of Usakos, gave maximum concentrations of 32 ppb and 35 ppb gold (Ash, 1987b), while a grab sample of hydrothermal shear-hosted magnetite-rich quartz veins on the edge of a mafic dyke yielded 1 g/t (Steven *et al*., 1994).

A bismuth sulphide/ochre vug in a pegmatite at the Rubikon Mine on the farm Okongava Ost 72, 25 km southeast of Karibib, contained 11.2 g/t gold (Miller, 1992b; Steven *et al*., 1994).

2.1.2.4 Anomalies

Badenhorst (1992) reported a soil-sampling anomaly of 479 ppb gold the farm Naob 69, 13 km southwest of Usakos.

Walker (1992) cited grab-sample and stream-sediment anomalies of 243 ppb and 4.26 ppb gold respectively on the eastern part of the farm Gross Aukas 68, 10 km south-southwest of Usakos.

All stream-sediment sampling done over the southern portion of Toanib 80, 20 km south of Karibib, returned results of less than 20 ppb gold (Landmark, 1987e).

2.2 Kamanjab Inlier, Huab Metamorphic Complex

2.2.1.1 Copper Valley Mine, Mesopotamie 504

Native gold is present in several quartz-copper veins cutting gneiss and schist of the Huab Complex at the defunct Copper Valley Mine, 65 km northwest of Khorixas. Six prospecting trenches were opened prior to 1914, and subsequently limited opencast mining was conducted in the early 1950s and early 1960s (Clynch, 1968).

The quartz veins that strike W10°N and dip 40°N are discontinuous and sporadically mineralised. They appear to be confined to subsidiary faults and shear zones where the country rock is locally altered to chlorite-sericite schist, talc, siderite and epidote (Söhnge, 1955 and 1958).

Granitic gneiss on the northeastern part of the farm contains sporadic copper-lead-bismuth-gold mineralisation in lenticular quartz pods that occur in fault zones striking east and dipping steeply to the north. Hand-cobbed chalcocite concentrates have been reported to carry 68.5 g/t gold, whereas galena concentrates contained 685 g/t gold (Clynch, 1968).

Gossanous carbonate-quartz veins contain visible gold along a prominent 1.5-km-long shear. Rock sample maximum concentrations of 43.8 g/t, 53.1 g/t and 127.6 g/t gold were reported by Berning (1986 and 1988). See the copper chapter for more detail.

2.2.1.2 Anomalies

Söhnge (1958) noted epigenetic gold mineralisation in veinlets and pegmatites in a shear zone on the farm Tzamin 228, 30 km north of Outjo, which does not appear to be related to the known copper mineralisation.

Traces of gold in limonite associated with copper mineralisation occurring in quartzite interbedded with quartz porphyry were found by Labuschagne (1976) on Bergvallei 604, 20 km west of Kamanjab.

Anglo American Prospecting Services Namibia (AAPSN) conducted a sampling programme in 1989 over several farms some 30 km west of Khorixas (Marsh *et al*., 1989). See Table 1 for results.

2.3 Vioolsdrif Intrusive Suite

2.3.1.1 Haib copper Deposit, Tsams 685

The large, low-grade porphyry copper deposit, 40 km east of Noordoewer, contains only small amounts of gold. The maximum assay result obtained was 0.02 g/t and the remaining samples yielded only trace amounts of gold (Cooke, 1973, 1975 and 1977; Minnitt, 1979). See the copper chapter for a detailed description of geology and mineralisation.

2.3.1.2 Kromrivier 359 Anomaly

All samples of pyritic rhyolite tuff from the copper prospect on Kromrivier 359, 35 km east of Noordoewer, gave assay results below 0.05 g/t gold (Lee, 1975).

2.4 Hohewarte Metamorphic Complex

2.4.1.1 Oamites Mine, Oamites 53

The Oamites Mine is situated 45 km south of Windhoek, just west of the Windhoek–Rehoboth national road. A 55-m-wide and 600-m-long stratiform orebody is situated on the lithofacies change from terrestrial arenites to marine sediments. Although only traces of gold have been detected in association with the copper mineralisation, gold was recovered as a by-product from the blister copper produced by the mine between 1971 and 1984 (Lee and Glenister, 1976; Killick, 1986). See the copper chapter for more detail.

2.5 Khoabendus Group

2.5.1 Otjovazandu Formation

2.5.1.1 Gelbingen 630 Deposit

A gossan on Gelbingen 630, 25 km northwest of Kamanjab, contained in tuffs, quartzites, cherts and shales, was systematically chip-sampled by Stockwell (1973). Many localities contained sample values in excess of

Table 1: Kamanjab inlier gold sampling assay results (AAPSN, Marsh et al., *1989)*

Farm	Stream-sediment sampling	Rock sampling	Soil sampling
Halt 379	-	296 ppb, 352 ppb,	-
		377 ppb & 2 x > 1000 ppb	-
Bergville 490	3.16 ppb, 6.00 ppb & 15.80 ppb	-	-
Oas 493	3.16 ppb to 17.60 ppb	-	-
Lofdal 491	1.20 ppb	25 ppb	6.0 ppb
Tussenby 729	3.62 ppb, 4.00 ppb,		
	6.13 ppb & 6.26 ppb	-	-

3 g/t gold. A grade of 2.7 g/t gold was obtained in a borehole at a depth of 45 m.

2.5.1.2 Occurrences

Most samples taken from a gossan in sheared quartzites located some 60 km northwest of Kamanjab gave assay results of up to 0.1 g/t gold. Table 2 shows the anomalous assays recorded by Barbour (1982).

Table 2: Otjovazando Formation gold assay results (Barbour, 1982)

Farm	Anomalous gold assays
Tevrede 643	11.5 g/t, 16.0 g/t, 50.0 g/t & 52.0 g/t
West End 642	6.2 g/t
Marenphil 641	9.35 g/t &41.0 g/t

Du Plessis (1983), Hartleb (1984), Hart (1988), Pauli (1990), Smit (1991) and Petzel (1995) have carried out further work on the farm Tevrede 643. See the copper chapter for more detail.

2.5.1.3 Anomalies

Martin (1965) noted gold mineralisation hosted in metaquartzite at the Otjovazondo/ Khoabendus Prospect, 5 km north of Otjovazando.

Sampling by Barbour (1982) of a gossan in sheared quartzites on the farm De Ville 638, 60 km northwest of Kamanjab, gave assay results of 0.1 g/t gold with a maximum value of 0.29 g/t gold.

Whole-rock and soil sampling by Gresse (1983) and Brewer (1989) returned maximum concentrations of 47 ppb, 57 ppb, 60 ppb and 67 ppb gold on the farm Welkom 294, 120 km northwest of Outjo.

2.6 Rehoboth Sequence

The gold mineralisation within the Rehoboth Sequence is primarily associated with the pegmatitic phase of granite intrusions that resulted in numerous quartz veins and stringers within Rehoboth Sequence rocks and intruding granites. The auriferous quartz veins often carry small amounts of galena and copper minerals. The gold deposits, although very rich in places, are generally small and show extremely irregular enrichment (Anon, 1967). (Fig. 2, Table 3)

Table 3: Gold production in the Rehoboth area - 1934 to 1949 (Source: Directorate of Mines)

Year	Production (kg)
1934	0.591
1935	44.621
1936	69.388
1937	33.662
1938	9.632
1939	2.046
1940	3.504
1941	2.091
1947	0.222
1948	14.626
1949	1.102
Total	181.485

2.6.1 Neuhof Formation

2.6.1.1 Neuras Gold Mine, Neuras 330

The supergene-enriched gold ore at the Neuras mine, 20 km southwest of Rehoboth, is associated with copper mineralisation. A sheared and metamorphosed mafic dyke on the contact between Piksteel Granodiorite and Neuhof Formation chlorite-amphibolite schist strikes N60°W and outcrops over a distance of 500 m, dipping from 80°S to 60°N. Thickness varies from a few millimetres to 60 cm. The gold mineralisation is associated with copper sulphides, pyrite and galena. The oxidised zone is characterised by the secondary minerals malachite, azurite, chrysocolla, hematite and limonite. Free gold in the form of flakes and

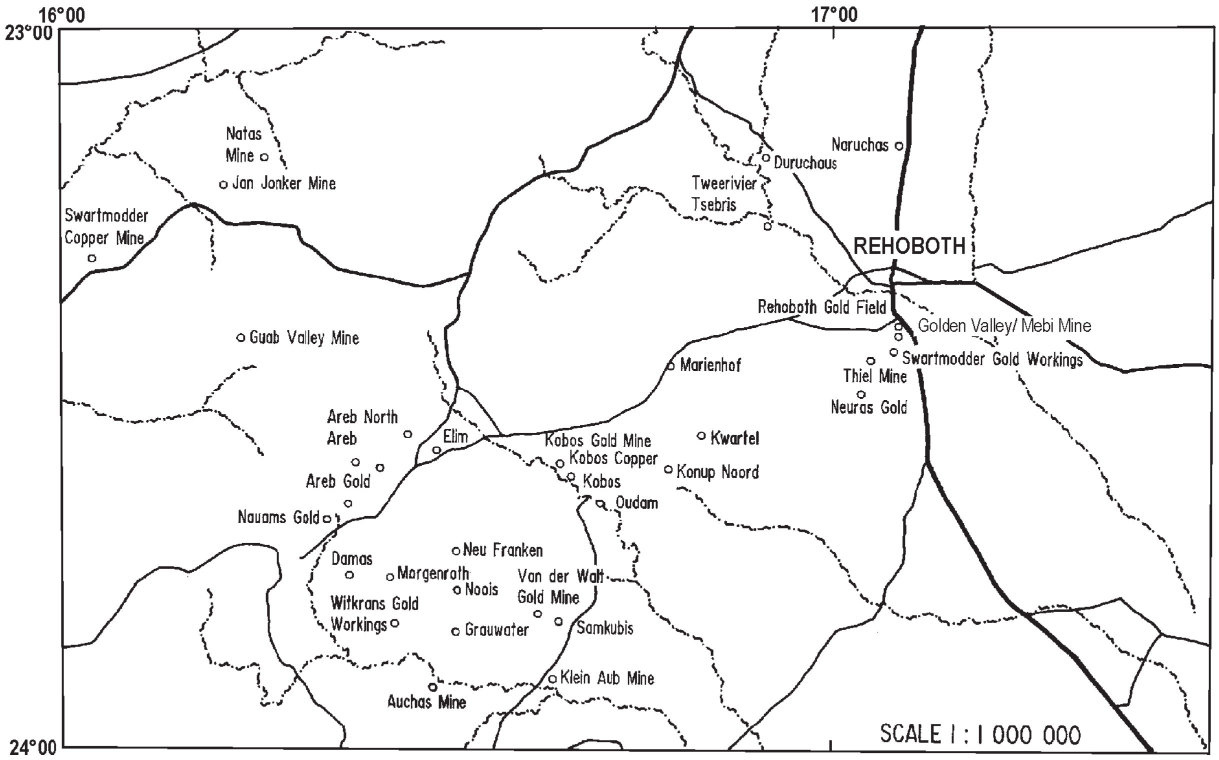

Figure 2: Locality map of the Rehoboth gold fields

nuggets occurs within this zone (Borton, 1976) (Fig. 3).

Gold production from the oxidised zone, mined between 1936 and 1938 to a depth of 60 m, totalled 31.47 kg, while concentrates contained 68.5 g/t gold (De Kock, 1930 and 1932; Kovaloff, 1933; Anon, 1964 and 1967; Whitfield, 1990).

More recent surface investigations have shown that gold is associated with lenses of smoky quartz containing pyrite, chalcopyrite and magnetite over a strike length of 300 m. However, grades and widths vary considerably. Several drillholes intersecting the shear zone indicated that the highest gold grades are always associated with magnetite rather than pyrite (Borton, 1975).

Maximum grades obtained in the oxidised zone, which extends vertically to some 70 m below surface, were 7.1 g/t gold over 2 m; the sulphide zone maximum grade was 3.7 g/t over 62 cm. Reserves total 76 640 t at a grade of 7.06 g/t (Borton, 1975).

Further exploration resulted in a maximum grade of 9.1 g/t being obtained from a similar geological setting approximately one kilometre to the northeast of the old mine (Borton, 1976 and 1978; Whitfield, 1990).

2.6.2 Elim Formation

2.6.2.1 Kobos Copper and Gold Mines, Kobos 321

The dormant Kobos copper mine, 55 km southwest of Rehoboth, produced only minor gold during its life (see copper chapter for more detail). However the Kobos gold mine, located some 4 km southeast of the copper deposit, produced a total of 35.454 kg of gold between 1935 and 1941 (Anon, 1964).

Gold-bearing quartz veins containing hematite, limonite and malachite occur in chlorite schist and sericitic quartzites that are interpreted as a metamorphosed felsic to intermediate volcanic rocks. The veins vary in thickness from a few centimetres to 60 cm, strike approximately east–west for a distance of about 3 km and dip from 70^{o} to 85^{o} to the north.

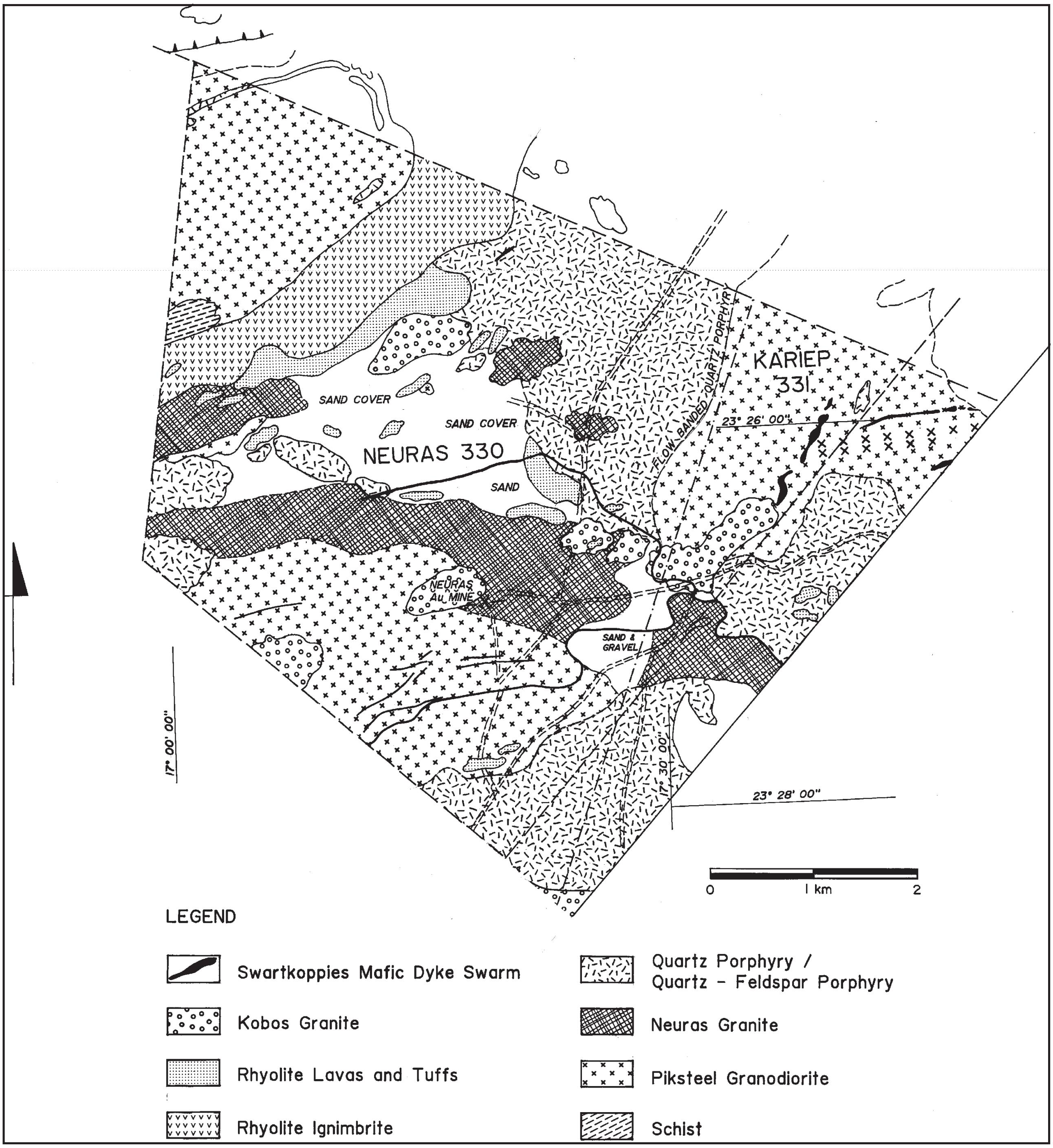

Figure 3: Geological map of the Neuras gold mine (Borton, 1978)

Enrichment occurred along slight folding as evidenced by extensive but relatively shallow stoping on such structures along the approximately 3-km strike length. The supergene-enriched gossanous oxide zones capping the primary sulphide mineralisation were the main source of past gold mining (Anon, 1967; Cooke, 1965b; Evans, 1979).

More recent exploration drilling produced assay results of 3.38 g/t, 3.60 g/t, 4.05 g/t and 4.88 g/t gold (Brewitz, 1974). A grab sample contained 17.0 g/t gold (Evans, 1979).

2.6.2.2 Witkrans Gold Workings, Witkrans 342

Also known as the “Quasi-Modo West and East Mine”, the Witkrans Gold Mine is situated 80 km southwest of Rehoboth within Elim Formation rocks, on the contact with Piksteel Granodiorite (Snowdowne, 1964). The lenticular, en-echelon, sheared hydrothermal quartz veins have limited strike length and erratic gold content (Labuschagne, 1977). The old workings have attracted several investigations over the years (Cooke, 1961; Callesen, 1963; Snowdowne, 1964; Labuschagne, 1977; Misiewicz, 1983; Bowen, 1986; Petzel and Roesener, 1987). Best results obtained from trench sampling were 3.85 g/t gold over 75 cm and 18.79 g/t gold over 91.44 cm (Labuschagne, 1977).

2.6.2.3 Occurrences

On the southern portion of the farm Morgenroth 17, 73 km west-southwest of Rehoboth, old workings exist on vertical east–west striking sheared mafic dykes within Elim Formation rocks (Anon, 1967). The main working is 40 m long and 10 m deep (Snowdowne, 1964). Anomalous results from exploration in the 1980s were 2.55 g/t, 3.60 g/t, 4.39 g/t gold and three samples with 5.0 g/t gold (Petzel, 1986a; Roesener, 1987; Petzel and Roesener, 1987; Freyer, 1990).

On the farm Noois 337, 90 km west-southwest of Rehoboth, granites and granodiorites of the Nauchas Suite (Snowdowne, 1964; Anon, 1967) have intruded Elim Formation volcano-sedimentary rocks. Gold mineralisation is not restricted to any one lithology but rather to narrow (15 cm), crosscutting east–west trending vertical shear zones which are interpreted to be of epithermal hot-spring origin (Misiewicz, 1983). More recent sampling of quartz veins yielded maximum gold concentrations of 1.03 g/t, 1.30 g/t, 2.44 g/t, 3.85 g/t, 13.6 g/t, 14.8 g/t and 29.3 g/t (Misiewicz, 1983; Bowen, 1986; Petzel, 1986a; Roesener, 1986; Petzel and Roesener, 1987).

Past production on Samkubis 516, 90 km west-southwest of Rehoboth, totalled 23.23 kg from a 20-m-long quartz vein hosted by amphibolitic country rocks (Anon, 1967). The gold mineralisation seems to be related to metasomatised mafic dykes and shear zones crosscutting the Piksteel Granodiorite/Elim Formation contact (Snowdowne, 1964). More recent assays of gossanous, ferrugenous hydrothermal quartz veins on the farm returned maximum values of 1.20 g/t, 1.32 g/t and 2.50 g/t gold (Misiewicz, 1983; Bowen, 1986; Petzel and Roesener, 1987).

2.6.2.4 Anomalies

Martin (1965) noted that the oxidised zone of a veined lens on Kobos 321, 55 km southwest of Rehoboth, had previously been mined for gold. Sampling of the gossan by Smalley (1981) gave results up to 0.09 g/t gold.

A volcanogenic-exhalative deposit was noted by Misiewicz (1983) and Petzel (1986a) on the farm Neu Franken 216, 67 km west-southwest of Rehoboth.

Rock sampling by Freyer (1990) on Neu Franken 216 and Elim 214, 68 km west-southwest of Rehoboth, gave maximum concentrations of 834 ppb and 133 ppb gold respectively.

2.6.3 Marienhof Formation

2.6.3.1 Swartmodder Gold Workings, Rehoboth Townlands 302

Irregular 30- to 100-cm-wide hydrothermal quartz veins on the contact beteween gossanous granite and metasediments 8 km south of Rehoboth, contain hematite, limonite, pyrite and malachite (Burg, 1942; Cooke, 1965b). The deposit produced 32.53 kg of gold between 1935 and 1938 and was the largest workings at the time (Anon, 1967). Killick (1986) and Whitfield (1990) have conducted more recent exploration work. A grab sample contained 2.526 g/t gold.

2.6.3.2 Swartmodder Copper Workings, Rehoboth Townlands 302

The Piksteel Granodiorite and granites of the Gamsberg Suite 6 km south of Rehoboth, intrude schists, micaceous quartzite and metalavas of the Marienhof Formation. Copper mineralisation occurs mainly in sheared lava and schist xenoliths in granite (Martin, 1965; Ransom, 1975). The gold content of this copper deposit is generally low and ranges from trace amounts to 8.0 g/t in exceptional cases (Rimann, 1915). No gold production has ever been recorded (Anon, 1964). Subsequent investigations have failed to prove economic gold mineralisation (Walden, 1983). See copper chapter for details.

2.6.3.3 Golden Valley Mine, Rehoboth Townlands 302

Mining operations can be traced back to the early 1930s when the mine was initially known as the "Kobie De Wet Mine" and later as "Mebi Mine". The deposit, located 7 km southwest of Rehoboth, was reopened in 1983 as the Golden Valley Mine (Fig. 4), but was closed again in 1994 due to erratic grade distribution. A small carbon-in-pulp process was applied to the milled ore. An 8- to 24-hour carbon loading cycle followed a 24-hour leaching cycle. The loaded charcoal was sent to South Africa for final treatment.

The Marienhof Formation host rocks are composed of metapelitic to psammitic units intercalated with metavolcanic sequences. Quartz-hosted gold is present mainly in a 2-m-wide shear zone, dipping 45° north-northeast.

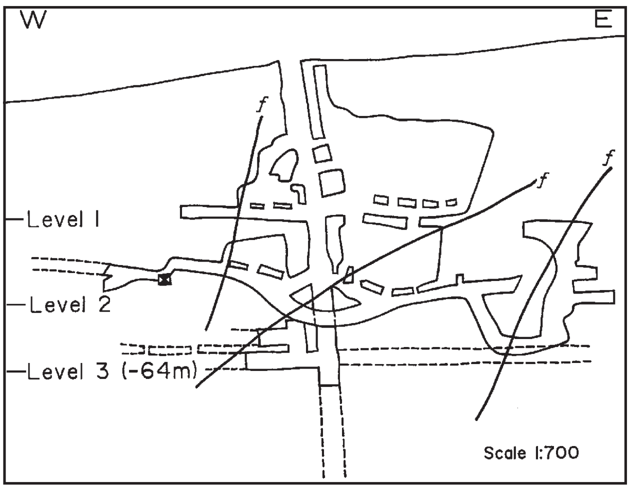

Figure 4: Sectional view of the Golden Valley Mine (Siebeck, 1994)

The gold is associated with specularite/ hematite-rich portions of the shear zones, resulting from supergene enrichment by percolating surface waters. The patchy mineralisation was proven over a strike length of 7 km and depths of 150 m at an average grade of 3.5 g/t gold.

2.6.3.4 Van der Walt Gold Mine, Samkubis 516

The Van der Walt Gold Mine on Samkubis 516 is situated 90 km west-southwest of Rehoboth. Production figures from 1937 to 1941 indicate that 26.2 kg gold was mined from hydrothermal veins associated with lava flows (Anon, 1964). Grab samples taken returned values of 0.10 g/t, 0.20 g/t and 0.43 g/t gold (Shelford, 1975).

2.6.3.5 Occurrences

A supergene-enriched pyritic gossan on the farm Marienhof 49, 30 km west-southwest of Rehoboth, produced 6.75 kg gold in 1935 and 1936 (Anon, 1964). However, the erratic nature of the mineralisation made it uneconomic (De Kock, 1934). Subsequent sampling by Smalley (1981) gave a range of 0.12 to 1.88 g/t gold with a maximum of 5.58 g/t gold.

Innes and Buerger (1975) sampled a magnetite-quartzite banded iron formation boudin within sandy schist on the farm Rostock Süd 414, 150 km east-southeast of Walvis Bay, which returned a value of 1.05 g/t gold.

2.6.3.6 Anomalies

Irregular gold mineralisation in copper sulphide-rich pegmatitic quartz veins has been reported on the farm Konup Noord 355, 15 km northwest of Rehoboth (Burg, 1942).

Gold has also been found on Kwartel 324, 27 km west-southwest of Rehoboth, and at Thiel Mine, Rehoboth Townlands 302, 16 km south of the town (Anon, 1967).

2.6.4 Gaub Valley Formation

2.6.4.1 Jan Jonker Mine, Kos 28/Chaibis 29

The defunct mine in the northeastern corner of the farm Kos 28 on the border of Chaibis 29, 85 km west of Rehoboth, was worked for gold and copper as early as 1850. The disseminated mineralisation is found in chloritic schist adjacent to quartz veining (Reuning, 1925; Worst, 1970).

2.6.4.2 Anomalies

Rock sampling by Freyer (1990) on Areb North 202, 67 km west-southwest of Rehoboth, gave maximum gold concentrations of 140 ppb and 148 ppb.

Quartz veins in schist were mined for gold in 1936-37 in the Gaub Valley on Weener 193, 80 km west of Rehoboth, producing 1.7 kg gold (Anon, 1964 and 1967).

2.7 Namaqualand Metamorphic Complex

Von Berkel (1986) sampled volcanic plugs on the farm Kanabeam 331, 120 km west of Karasburg, with disappointing results; most assays failed to detect gold and maximum concentrations were 15 ppb and 20 ppb gold.

On the farm Haruchas 10, 35 km west of Grünau, a mineralised shear zone gave a soil sample maximum value of 15 ppb gold and a rock sample maximum concentration of 434 ppb gold (Freyer, 1991).

2.8 Alberta Complex

Gold has been reported in quartz veins on the farms Nauchas 14 and Areb 176, about 75 km west-southwest of Rehoboth (Anon, 1967). Rock sampling by Freyer (1990 and 1991) on the farms returned maximum values of 215 ppb and 189 ppb gold respectively.

2.9 Piksteel Granodiorite

Rimann (1915) noted the presence of gold on the farm Auchas 347, 80 km southwest of Rehoboth. A more detailed report by De Kock (1934a) described the Auchas Mine geology as an anastomosing quartz vein stockwork with copper mineralisation. Average gold values are given as 0.6 g/t gold, but restricted secondary enrichment yielded results of up to 41 g/t gold (De Kock, 1934a). Söhnge (1961) reported that copper mineralisation and minor gold were associated with narrow chloritic schist lenses, each a few metres in length, and with branching quartz veins up to 2 m wide. Subsequent exploration was undertaken by Rand Mines (Snowdowne, 1964) and Kappa Mining (1974).

Near the eastern boundary of the farm Oudam 354, 50 km southwest of Rehoboth, two showings of copper oxides, about 500 m apart, are located in a 200-m-wide belt of altered Piksteel Granodiorite. A grab sample of a vein within the altered granodiorites contained 1.8 g/t gold (Woodsend, 1974). See copper chapter for more detail.

2.10 Sinclair Sequence

2.10.1 Nagatis Formation

2.10.1.1 Mooifontein 50 Deposit

Sheared quartz veins in sericite and chlorite schist contain pyritic gold mineralisation on the farm Mooifontein 50, 18 km southeast of Helmeringhausen. Drilling revealed narrow conformable bands of massive pyrite with minor chalcopyrite containing up to 1.36 g/t gold over 140 cm (Gallo, 1974). See copper chapter for more detail.

2.10.2 Kunjas Formation

2.10.2.1 Korias 28 Deposit

Conglomerate-hosted gold mineralisation on the farm Korias 28, 30 km west of Helmering-hausen, has been known for some time (Beetz, 1923). The deposit has been drilled and a best result of 2.65 g/t gold over 41 cm was obtained from a limonitic vein (McMagh, 1986).

2.10.2.2 Old Campbell Mine, Kunjas 14

The occurrence of limonite-quartz-carbonate veins in conglomerate and associated with a sheared mafic lava, known as the Old Campbell Mine on the farm Kunjas 14, 14 km west-southwest of Helmeringhausen, has been mentioned by Beetz (1923) and Martin (1965). Rock sampling by Simmonds (1991) returned maximum concentrations of 20.2 g/t, 26.1 g/t and 87.3 g/t gold. See copper chapter for more detail.

2.10.2.3 Anomalies

Panning of conglomerate-hosted mineralisation by B&O Minerals (1976) approximately 70 km northeast of Helmeringhausen on the farms Saffier 148, Campbell’s Valley 57, Kumbis 55, Sonop 105, Spes Bona 62 and Vergenoeg 56, found traces of gold.

2.10.3 Barby Formation

2.10.3.1 Sinclair/Itah Mine, Sinclair Mine 2

Gold associated with copper mineralisation occurs in the dormant Sinclair/Itah Mine, 70 km north of the Aus railhead. Host rocks comprise a volcano-sedimentary unit of intermediate and felsic lavas, intensely epidotised in places in the upper zones, with quartzites and conglomerates at the base.

Quartz-filled fractures in slightly folded porphyritic rhyolites and vesicular andesites have been chip-sampled. Gold values were erratic with the maximum concentration obtained being 48.75 cm.g/t gold (Futcher and Legg, 1964). See copper chapter for more detail.

2.10.3.2 Swanson’s Claims, Aruab 23

Rock grab sampling of a gossanous chert breccia by Hart (1985) on Swanson’s Claims on the farm Aruab 23, 140 km southwest of Gibeon, gave anomalous results of 0.11 g/t, 0.12 g/t, 0.16 g/t and 0.22 g/t gold. See copper chapter for more detail.

2.10.4 Aubures Formation

2.10.4.1 Kobos 321 Anomaly

Several small supergene-enriched oxidised zones on the farm Kobos 321, 55 km southwest of Rehoboth, have been worked erratically in the past (De Kock, 1934a; Martin, 1965; Cooke, 1965b). The stratabound mineralisation within an acid to intermediate volcanic sequence is of volcanic origin, with tectonism-related quartz veins remobilising the gold at a later stage (Evans, 1979; Killick, 1986). Sampling by Smalley (1981) over the farm produced results of up to 0.09 g/t gold. Compare with 2.6.2.1.

2.10.4.2 Naris 375 Anomaly

Visible gold nuggets up to 5 mm in size were recently recovered by local residents in a 40-m deep borehole on the farm Naris 375, 22 km south of Rehoboth (1997, Pers comm.).

2.10.5 Undifferentiated

Soil samples from Duwisib 84, 125 km west of Gibeon, exhibited concentrations of 0.11 g/t, 0.18 g/t and 0.42 g/t gold as reported by Hart (1989).

Grab sampling of a sericitic quartz vein in rhyolite on the farm Grauwater 341, 80 km west-southwest of Rehoboth, gave maximum concentrations of 140 ppb, 143 ppb and 150 ppb gold (Petzel, 1986a).

2.11 Sinclair Sequence Equivalents

2.11.1 Gamsberg Granitic Suite

2.11.1.1 Damas 344 Copper Deposit

Although no gold has been detected associated with the known porphyry copper occurrence on the farm Damas 344, 80 km west-southwest of Rehoboth (Snowdowne, 1964), irregular cherty quartz veins in schistose country rock are auriferous (Anon, 1967). Grab sampling of the ferrugenous quartz vein float gave elevated concentrations of 68 ppb, 340 ppb and > 3000 ppb gold (Petzel, 1986b).

2.11.2 Klein Aub Formation

2.11.2.1 Klein Aub Mine, Klein Aub 350

The sediment-hosted copper sulphide deposit, 70 km southwest of Rehoboth, contains minor gold. The maximum grade recorded is 0.066 g/t gold (Handley, 1965; Martin, 1965; Ruxton, 1986; Tregoning, 1987; Borg, 1987; Borg *et al*., 1987 and 1988). See copper chapter for more detail.

2.12 Numees Formation, Gariep Complex

The Lorelei porphyry copper deposit, situated 20 km north-northeast of Sendelingsdrift, contains mineralised veins on a gneiss/schist contact which carry gold (Martin, 1965; Viljoen *et al*., 1986). See copper chapter for more detail.

3. Gold Occurences in the Damara Sequence and Related Rocks

Gold mineralisation is located predominantly within the Central and Northern Zones of the Damara Sequence in five main settings (Steven *et al*., 1994) (Fig 5):

- East-northeast trending megashear zones and chlorite-magnetite rocks on the margins of metadolerites in the Abbabis basement inlier.

- Minor auriferous veins in Nosib Group quartzites.

- Au-Bi-As-Te mineralisation in quartz veins and associated skarn alteration in Swakop Group marbles and calc-silicates.

- Alteration zones in pyroclastic portions of Daheim Member metavolcanic rocks.

- Au-As-W-Bi mineralisation in quartz veins and both dilational and mylonitic structures in Swakop Group metapelites and metaturbidites.

Gold mineralisation is associated with late-tectonic, commonly linear, late-D_3 and D_4 structures. Both metamorphic and magmatic fluids are implicated in the formation of the central Namibian gold deposits.

Two gold provinces are distinguished in the Central Zone (Steven *et al*., 1994):

- South of the Omaruru lineament (Southern Central Zone), an influx of auriferous fluids may well have occurred via major crustal structures that penetrate deep into the granitic basement. Au-Bi mineralisation was concentrated in the viscinity of late-tectonic leucogranites and lithium pegmatites or veins along major lineament systems.

- In the Northern Central Zone (and Northern Zone), Au-As mineralisation is located in ductile, semi-ductile and brittle structures in the pelitic sediments of the Oberwasser and Kuiseb Formations. In the Central Zone, where peak metamorphic conditions (amphibole facies) were notably higher than in the Northern Zone (greenschist facies), the two metals were concentrated in the aureoles of late-tectonic granitic and pegmatitic intrusions.

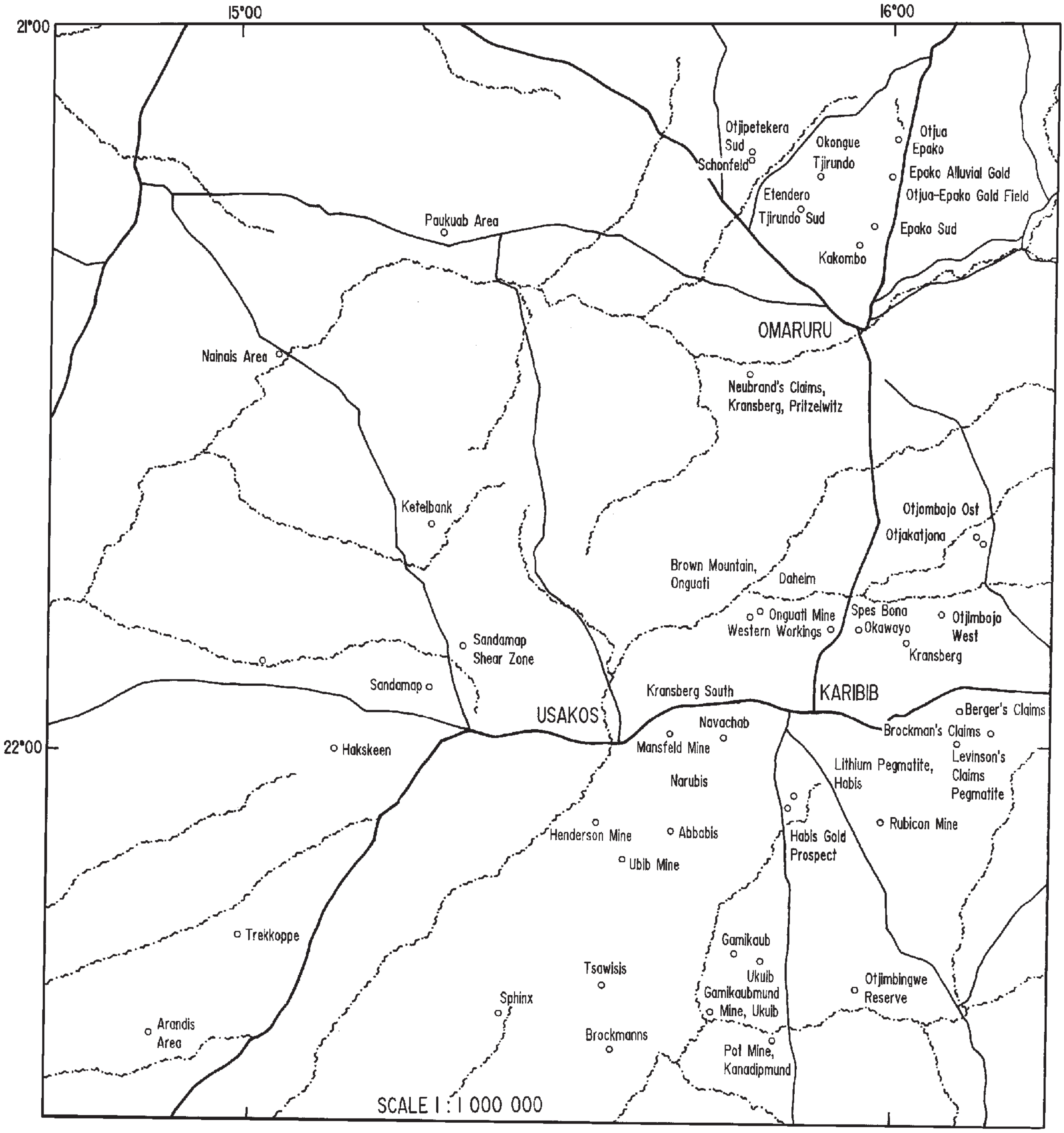

Figure 5: Gold occurrences in the Damara Sequence.

3.1 Southern Platform

3.1.1 Hakos Group - Kudis Subgroup

3.1.1.1 Undifferentiated

Brewer (1988) sampled gossanous quartz veins on the farm Dorka 206, 40 km west of Witvlei. The maximum assay value obtained was 0.07 g/t gold.

3.2 Southern Margin

3.2.1 Hakos Group - Kudis Subgroup

3.2.1.1 Blaukrans Formation

3.2.1.1.1 Natas Mine, Natas 220

Quartz-feldspar veins and pegmatites in chloritic schists were mined between 1913 and 1919 for scheelite and copper mineralisation with associated gold on the farm Natas 220, 85 km west-southwest of Rehoboth. Approximately 0.88 kg of gold was produced from concentrates containing 0.2 g/t to 4.8 g/t gold (Reuning, 1925; De Kock, 1934a; Anon, 1964). A grab sample taken from the old workings contained 218 g/t gold (Worst, 1970). See tungsten chapter for more detail.

3.2.1.1.2 Natas 220 Occurrence

Post-tectonic hydrothermal veins containing tungsten and copper mineralisation with free gold occur elsewhere on the farm Natas 220 (see 3.2.1.1).The maximum gold detected is 2.89 g/t (De Kock, 1934a; Miller, 1983a.).

3.2.2 Swakop Group

3.2.2.1 Chuos Formation

3.2.2.1.1 Groot Aub 267 Deposit

Drilling of a malachite-rich dolomite-quartz-mica schist contact on Groot Aub 267, 45 km south of Windhoek, yielded values of 0.20 g/t and 0.25 g/t gold obtained over an unspecified width (Lawless, 1975). See copper chapter for more detail.

3.3 Southern Zone

3.3.1 Nosib Group

3.3.1.1 Duruchaus Formation

Irregular sulphide-rich pegmatitic quartz veins have been recorded on the farms Duruchaus 249 and Tweerivier 307 (Anon, 1967). On Duruchaus 249, 25 km northwest of Rehoboth, gold is associated with bornite, while on Tweerivier 307, 20 km northwest of Rehoboth, quartz veins with patchy malachite show traces of gold and silver (De Kock, 1934a). See copper chapter for more detail.

Sheared pegmatite and quartz blows on Tsebris 48, 25 km west-northwest of Rehoboth, are known to be auriferous (De Kock, 1934a). See the copper chapter for more detail.

3.3.2 Hakos Group - Kudis Subgroup

3.3.2.1 Waldburg Formation

Newmont South Africa Limited (1975) detected a maximum of 0.5 g/t gold in dolomite-hosted quartz veins on the farm Naruchas 254, 20 km north of Rehoboth.

3.3.3 Swakop Group

3.3.3.1 Kuiseb Formation - Matchless Member

3.3.3.1.1 Matchless Mine, Friedenau 16

The stratabound exhalative-volcanogenic massive base metal sulphide deposit occurs within magnetite quartzite associated with the Matchless amphibolite on the farm Friedenau 16, 20 km southwest of Windhoek and contains erratic (0.5 to 1.0 g/t) gold grades (Goldberg, 1976; Adamson and Teichmann, 1986). Up to 1983, a total of 14.58 kg of gold was produced. A detailed description of the Matchless Mine is given in the copper chapter.

3.3.3.1.2 Gorob and Hope Deposits

Grades of up to 12 g/t gold from Gorob, 100 km southeast of Walvis Bay, (Anon, 1967) have previously been reported. More recent investigations of these proximal volcanogenic massive sulphide deposits have located only minor gold (Killick, 1983; Cowey, 1984; Breitkopf and Maiden, 1988). See copper chapter for more detail.

3.3.3.1.3 Otjihase Mine, Von Francois Ost 60

The stratiform massive cuprous pyrite deposit, located in magnetite quartzite on the farm Von Francois Ost 60, 18 km northeast of Windhoek, is a Besshi-type volcanogenic deposit. It is the largest of the massive sulphide deposits associated with the Matchless Member

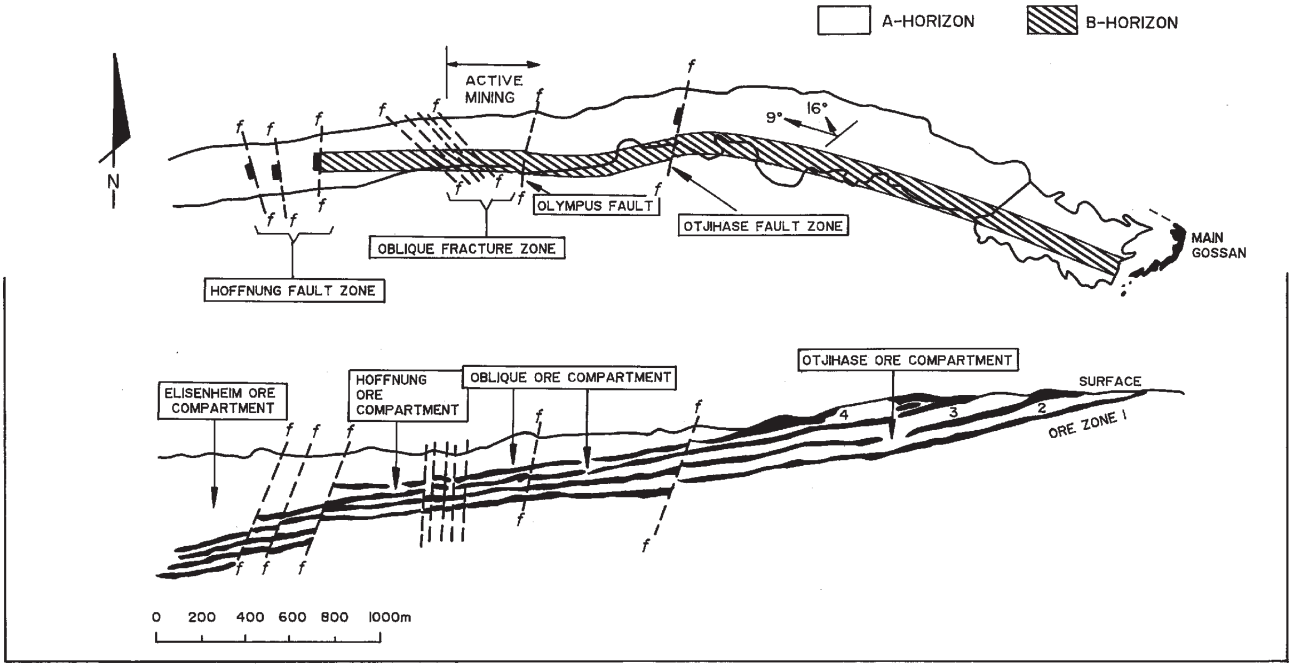

Figure 6: Otjihase Mine geological plan and section (Tsumeb Corporation Ltd)

(Goldberg, 1976) (Fig. 6). The 70 000 t per month mine produced gold as a by-product. The ore contains between 0.4 g/t and 1.4 g/t gold while the concentrate contains 4.0 g/t gold (Hartmann, 1994). See copper chapter for more detail.

3.3.3.1.4 Ongombo Gossan

The Ongombo gossan is located 43 km northeast of Windhoek on the farms Ongombo Ost 140 and Ongombo West 56. Kuiseb Formation biotite schists hosting Matchless Member amphibolites underlie the prospect. The Besshi-type mineralisation is closely related to the amphibolite and is exposed on surface as a moderately gossanous banded magnetite quartzite.

Three major ore shoots (West, Central and Ost) have been delineated by geophysical methods and drilling. The shoots plunge at 6× in a N35^{o}E direction. Ore grade and thickness increase down-plunge to the northeast (Petzel, 1994). Reserves have been estimated at 4.143 Mt containing 1.60% Cu, 8.92 g/t Ag and 0.21 g/t Au (Maneschijn, 1991).

3.3.3.2 Kuiseb Formation - Undifferentiated

3.3.3.2.1 Onganja Mine, Helen 235

The old Onganja mine, a copper-gold-molybdenum deposit, is situated 56 km northeast of Windhoek on the farm Helen 235, in a metamorphosed flysch succession of the Kuiseb Formation. An estimatd 0,2g/t gold is contained in the ore. Gossanous Material can contain up to 30g/t gold.

Quartzites, feldspathic quartzites, epidote-quartzites, amphibolitic schists, meta-gabbro and graphite schists are host lithologies to the mineralised veins. The post-metamorphic vein mineralisation is structurally controlled, with veining occurring in first-order tension and shear joints related to the isoclinal structure, and corresponds to the upper part of a hydrothermal system with non-pervasive sericite and albitic alteration (Charles, 1985).

Estimated reserves to a depth of 100 m are about 300 000 t containing 2% Cu with erratic gold grades between 0.1 g/t and 1.0 g/t (Esterhuizen, 1987). See copper chapter for more detail.

3.3.3.2.2 Thorn Tree Mine, Okamuvia 144

Located within the old Snyman's claims on Okamuvia 144, 60 km northwest of Windhoek, the Thorn Tree Mine was worked for its copper content before 1914 and sporadically in the 1950s and 1960s. A hydrothermal, brecciated quartz vein crosscutting quartz-biotite schist contains minor gold (Burg, 1942). See copper chapter for more detail.

3.3.3.2.3 Ganams 316 Occurrence

On the northern part of the farm Ganams 316, 90 km west of Windhoek, gold and copper are associated with a quartz vein, traceable over a strike length of 700 m. Discovered by a geochemical soil sampling survey, the composite samples taken about 100 m apart assayed between 0.2 g/t and 4.3 g/t gold (Scott, 1975).

3.4 Okahandja Lineament Zone

3.4.1.1.1 Rüdenau Nord 6

Drilling of a sulphidic quartz-biotite schist on the farm Rüdenau Nord 6, 25 km southwest of Okahandja just north of the Okahandja Lineament, proved the metasomatic deposit to be stratabound and auriferous with sample maximum values of 2.95 g/t and 6.15 g/t gold being obtained (Marsh, 1988). See also copper chapter.

3.5 Southern Central Zone

3.5.1 Nosib Group

3.5.1.1 Etusis Formation

3.5.1.1.1 Sphinx Mine, Nordenburg 76

Gold is associated with chalcocite-rich hydrothermal quartz veins in amphibolite facies meta-arkose at the Sphinx mine, 40 km south-southwest of Usakos (Smith, 1965; Anon, 1967). Soil sampling produced a maximum concentration of 565 ppb gold (Landmark G., 1987b), while a grab sample contained 0.35 g/t gold (Steven *et al*., 1994).

Rock sampling of quartz blows on Nordenburg 76 gave average assay values of less than 10 ppb gold with an anomaly of 99 ppb gold (Du Plessis and Clynch, 1968; Landmark G., 1987b).

3.5.1.1.2 Bergrus 94 Copper Occurrence

Gold is recorded in deep-level hydrothermal chalcocite- and malachite-bearing quartz veining in quartzite on the farm Bergrus 94, 40 km south-southwest of Usakos (Miller, 1983a). Mineralisation is associated with local shearing parallel to bedding and is truncated on one side against a granitic intrusion. Stream-sediment sampling over the occurrence revealed concentrations of 21 ppb gold (Landmark G., 1987c). However, follow-up work failed to confirm this.

3.5.1.1.3 Anomalies

Regional exploration sampling by Anglo American Prospecting Services produced anomalous assay values on farms 40 km south-southwest of Usakos. Follow-up work failed to locate any mineralisation. See Table 4.

3.5.1.2 Khan Formation - Tinkas Member

3.5.1.2.1 Gamikaubmund Mine, Ukuib 84

Situated directly east of the confluence of the Gamikaub and Swakop rivers, 47 km south-southeast of Usakos, the defunct mine in the past exploited on a small scale tectonically controlled quartz veins in fold hinges. Gold mineralisation is confined to calc-silicate horizons in a sequence of monotonous metaclastic rocks. Recent sampling of the old workings showed that the veining contains between 0.25 g/t and 1.79 g/t gold (Dekker, 1983; Esterhuizen, 1984; De Greef, 1988a).

Table 4: Etusis Formation sampling maximum values (AAPSN)

Farm	Soil sample	Stream-sediment sample	Reference
Bloemhof 109	trace	-	Landmark G, 1987d
Vlakteplaas 110	trace	-	Landmark G, 1987d
Southeastern portion of Valencia 122	trace	-	Landmark G, 1987d
Western portion of Modderfontein 131	trace	-	Landmark G, 1987d
Southern portion of Namibplaas 93	-	24, 29 & 48 ppb	Landmark G, 1987c
Southern portion of Tsawisis Süd 95	-	16 & 18 ppb	Landmark G, 1987c
Southern portion of Wolfkoppe 105	-	trace	Landmark G, 1987c
Horebis Nord 61	-	20, 23 & 27 ppb	Landmark V, 1988a
Okondura Nord 15	150 ppb	19 ppb	Land, 1988
Okondura Süd 162	1 & 30 ppb	20 ppb	Land, 1988

3.5.1.2.2 Pot Mine, Kanadipmund 83

A calc-silicate body 120 m long and 5 m thick located just south of the Swakop River, 50 km south-southeast of Usakos, hosts the abandoned Pot Mine. The mineralised calc-silicate is enclosed by granodiorite that shows assimilation of the calc-silicate on the contact. Soil-sampling assay values ranged between 0.04 g/t and 0.74 g/t gold while grab samples contained 7.65 g/t and 16.3 g/t gold (Dekker, 1983; Misiewicz, 1984; De Greef, 1988b).

3.5.1.3 Khan Formation - Undifferentiated

3.5.1.3.1 Khan Mine

The dormant copper mine located 7 km south of Arandis, was worked between 1915 and 1918, producing 32 454 t of copper ore. Once concentrated, the ore contained 0.39 g/t gold (Ramdohr, 1938; Söhnge 1939 and 1958; and Smith, 1965; Martin, 1965). See copper chapter for more detail.

3.5.1.3.2 Von Broen’s Claims Occurrence

A grab sample of itabirite, forming low-lying black hills approximately 16 km southeast of Walvis Bay, contained 5.25 g/t gold (Wagner, 1922).

3.5.1.3.3 Anomalies

Soil sampling over the farm Namibfontein 91, 38 km west-southwest of Usakos, produced an average assay value of 24 ppb gold with an anomaly of 53 ppb gold (Holman, 1987a).

Soil sampling over Sukses 90, 45 km west of Usakos, gave anomalous values of 23 ppb, 30 ppb, 34 ppb, 40 ppb, 77 ppb and 80 ppb gold (Stone, 1987a).

3.5.2 Swakop Group

3.5.2.1 Chuos Formation

Carr (1989b) detected a maximum of 418 ppb gold in rock samples taken from quartz veins on the farm Etiro 50, 20 km north-northeast of Karibib.

The maximum trench chip-sample result from a gossanous quartzite 12 km northwest of Arandis Siding was 153 ppb (Smalley, 1989).

3.5.2.2 Arandis Formation - Spes Bona Member

3.5.2.2.1 Eastern Zones Deposit, Navachab 58

Exploration for extensions of the Navachab deposit have detected two sets of quartz-sulphide veins of metasomatic origin in biotite schist to the east of the mine, which contain in excess of 50 g/t gold over an unspecified width (Steven *et al*., 1994).

Reverse-circulation drilling of the biotite-amphibolite schist was done over 5000 m to delineate vein-related skarn. A distal granitic source is suspected but has not been found (F. Badenhorst, Pers. comm.).

3.5.2.3 Arandis Formation - Okawayo Member

3.5.2.3.1 Navachab Mine, Navachab 58

Following an exploration agreement between AAPSN and Randgold in March 1982, the Navachab gold deposit was discovered in October 1984 during a base metal geochemical follow-up programme 10 km southwest of Karibib. Small gossan fragments collected from the site returned assay values of up to 11 g/t gold. Exploration drilling began the following year. A total of 14 721 m of diamond drilling (164 holes) and 2 930 m of reverse-circulation drilling (56 holes) was completed. An appraisal in 1986 was followed by a feasibility study in 1987, after which a decision was made to proceed with the development of the mine. Construction work began in 1988 and the first bar of gold was poured in December 1989.

The Navachab Gold Mine is now a wholly owned subsidiary of Erongo Mining & Exploration Limited, an Anglo American Ltd owned company. The opencast operation was brought into production at a cost of N$ 85 million. Currently, full production of 1.3 Mt of ore per year is mined at a grade of 2.56 g/t gold. Approximately 2 650 kg of gold is produced each year.

Power is drawn from the nearby NamPower 400 kV powerline. Water for the mine is sourced from the Swakoppoort Dam via an 85-km-long, 600-mm diameter concrete pipeline that also serves the town of Karibib. Although Navachab's water quota is 4 500 m^3 per day, only 3 400 m^3 per day is being used. The pipeline was constructed by the Department of Water Affairs at a cost of N$ 27.5 million, N$ 14.2 million of which will the repaid by Navachab by way of a fixed monthly tariff of N$ 83 000.

The gold deposits are associates with northwest–southeast trending strike-slip fault systems and associated subsidiary splays.

Footwall rocks are Nosib Formation quartzites and arkoses and Chuos Formation mixtites that occur on the south-eastern edge of the mining area. Spes Bona Member biotite

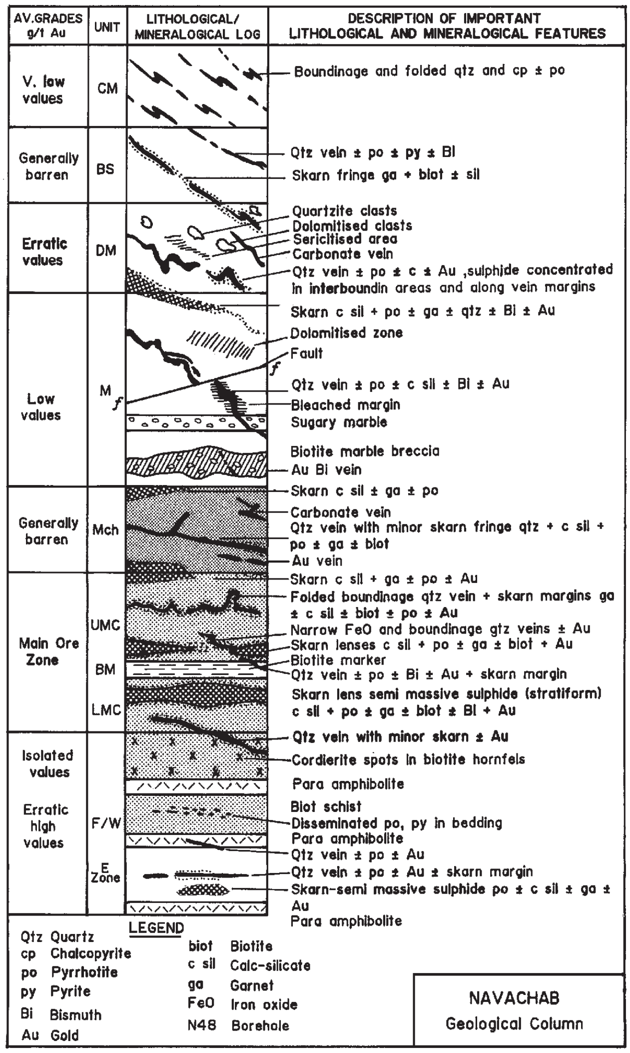

Figure 7: Stratigraphic column, Navachab Gold Mine (Navachab Gold Mine, 1997)

schists, interbedded with para-amphibolites and scattered marble lenses, form the immediate footwall (Fig.7). Abundant syngenetic pyrrhotite, and to a lesser extent pyrite, is present in the footwall rock types.

The Okawayo Member that hosts the main orebody locally consists of a 35-m-thick banded calc-silicate marble at the base (MC unit), a 5-m-thick amphibolite (MDMV unit), a 50-m-thick marble (M unit) and a 35-m-thick mottled dolomitic marble (DM unit) at the top. The metasediments strike northeast–southwest and dip 70^{o} to the northwest, plunging 22^{o}N (Fig. 8).

The Oberwasser Member interbedded siliclastic and metamorphosed volcanoclastic rocks immediately overlie the Okawayo Member carbonate unit.

The Karibib Formation forms a range of high hills to the northwest of the mine.

The footwall sequence and base of the Okawayo Member are intruded by numerous steeply dipping, northwest–southeast striking equigranular aplite and pegmatite dykes.

The marble-hosted gold-skarn mineralisation is related to multistage mineralisation. Some 800 m northeast of the main orebody, greisen and pegmatites are localised around a late-stage, bismuth-, fluorite- and boron-rich diorite, which is interpreted to be a possible heat source for the final concentration of the low-grade gold mineralisation.

Two styles of gold mineralisation can be recognised (Fig. 9). These are:

- Massive echelon skarn bodies within the MC unit elongated in an ENE–WSW direction and plunging at about 30^{o} to the north across the bedding. This zone hosts the bulk of the gold mineralisation and forms the main orebody at Navachab. Mineralisation within this zone is strata-bound but not stratiform. The gold mineralisation occurs with replacement lenses of pyrrhotite and minor pyrite,

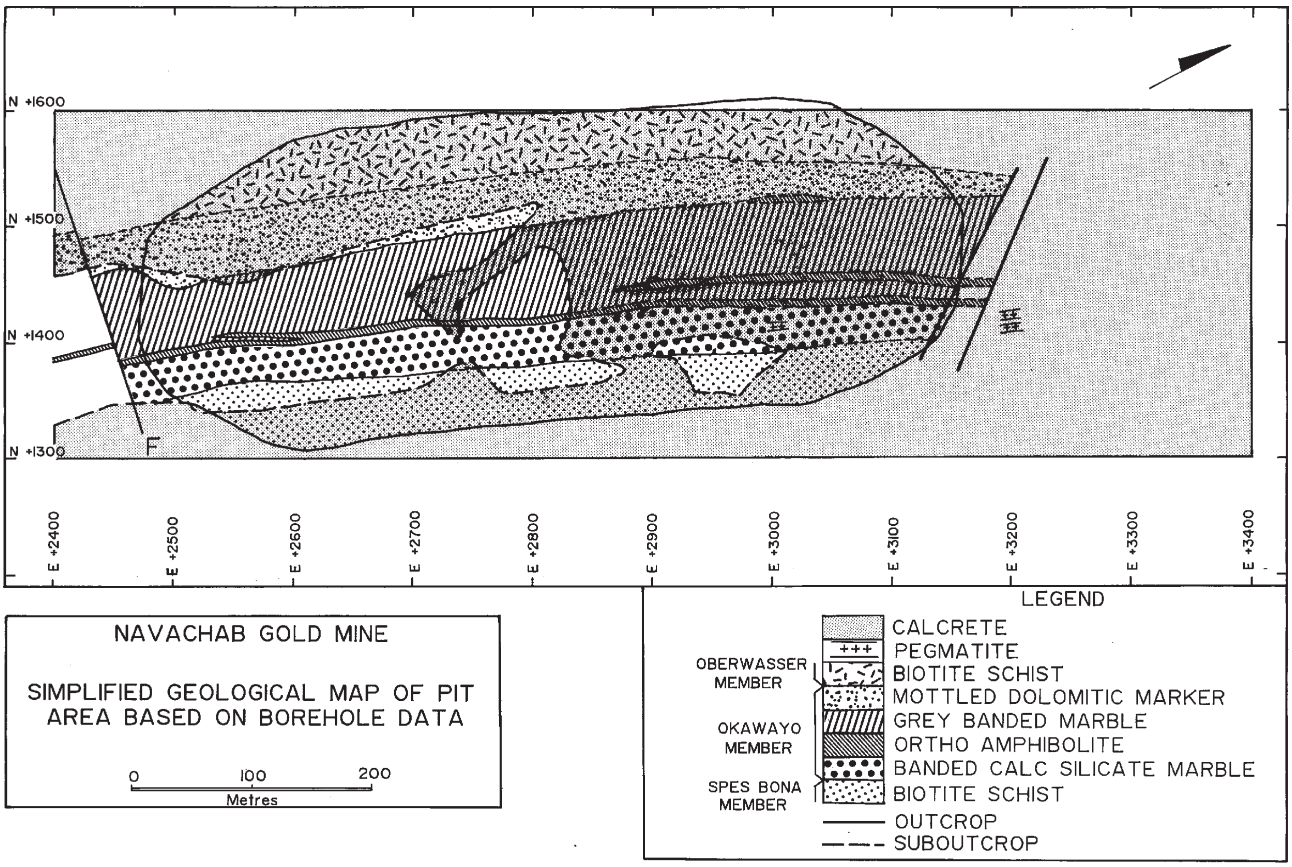

Figure 8: Geological map of the Navachab Gold Mine (Navachab Gold Mine 1997)

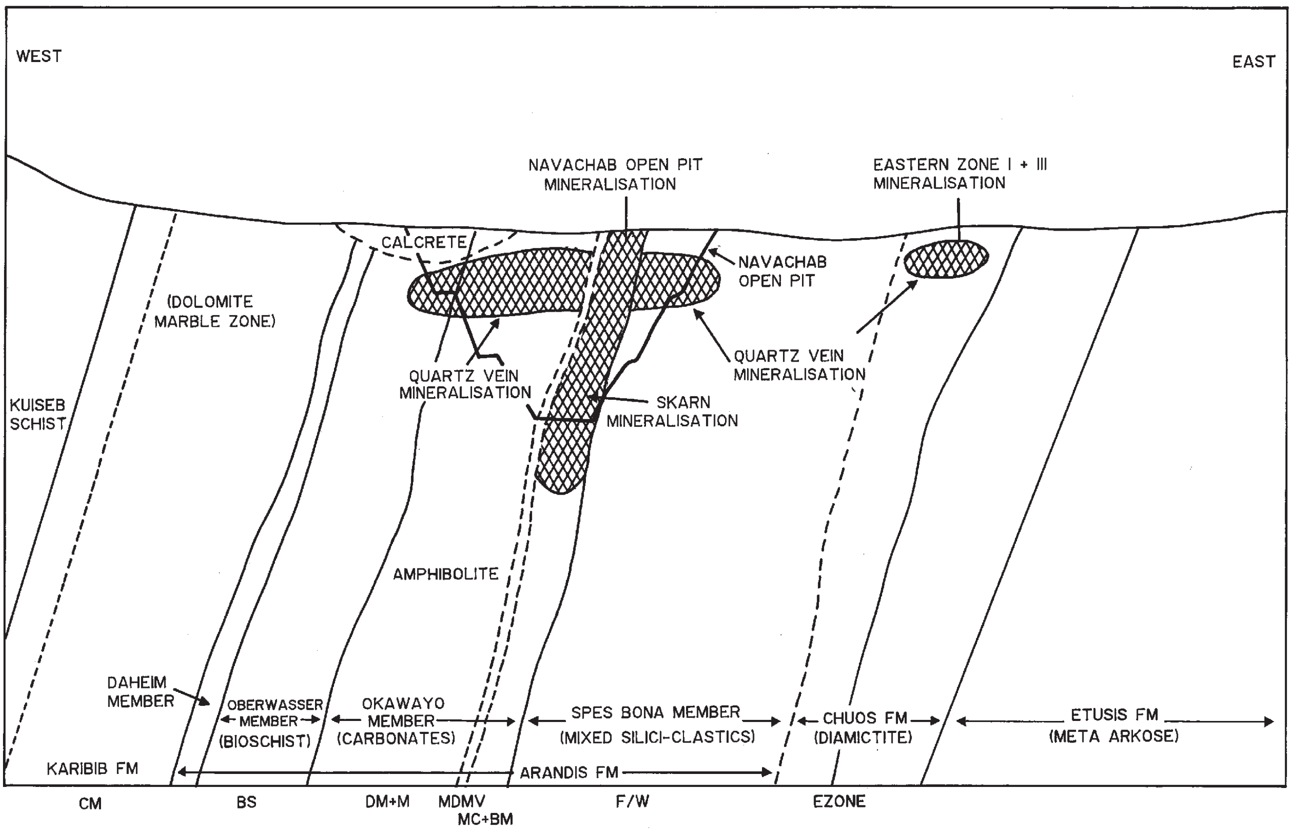

Figure 9: Cross-section through the Navachab orebody (line 2600) (Navachab Gold Mine, 1997)

chalcopyrite, calc-silicate minerals, garnet, biotite and quartz in the distinctly banded calc-silicate marble unit.

- The hanging wall banded grey marbles (M zone) and mottled dolomitic marbles (DM zone) host two sets of intersecting and crosscutting vein stockworks that also plunge to the north. Here the gold mineralisation occurs in the quartz-calcite veins that although individually exhibiting very high grades result in a low recoverable grade due to dilution as a result of the irregular vain frequency. Gold particle size tends to be coarser in this zone, which increases the nugget effect and makes ore/waste forecasting very difficult.

The bulk of the gold is present in fractures along grain boundaries in the calc-silicate minerals, accompanied by very fine quartz. Rare coarse gold is contained in a quartz-rich calcite-biotite gangue. Native gold accounts for more than 85% of the total gold, with most of the reminder occurring as maldonite (Au_2Bi). The gold to silver ratio is approximately 15:1.

Sulphides, mainly pyrrhotite with accessory pyrite, minor chalcopyrite and sphalerite are locally abundant and even massive. Scheelite is occationally associated with the sulphides. The sulphides do not host gold mineralisation although they are often in close proximity. None of the minor minerals is present in sufficient quantity to warrant recovery and, as far as is known, do not interfere in gold extraction.

Currently Navachab's ore reserve is 10.4 Mt at an average grade of 2.56 g/t and cut-off grade of 0.8 g/t, giving a life-of-mine of seven years. This should be extended once the ore reserves are recalculated after the two-year, 30 000-m reverse-circulation drilling programme is completed (mid 1997). An additional 3 000 m of drilling (RC with some diamond coring) is to be done to confirm the second shoot.

While management, exploration, mine planning, grade control and the plant are the responsibilities of Navachab itself, the mining operation is done under contract.

A geotechnical programme covering rock

joint mapping and slope stability surveys is done by consultants.

Blocks of ground of about 30 000 t are selected as blasthole batches that are designed not to cross over geological or obvious ore/ waste boundaries. Mining of 4.5 Mt per year is done in two 9-hour shifts per day, weekdays only. Blasting of benches to the required size of 700 mm is done using slurry explosives in two 5 m cuts. See Tables 5, 6 and 7 for mining details. A computerised grade control system is used to monitor samples taken from the blastholes. Roughly 10 000 samples per month are analysed in the Navachab laboratory, which has a two-day turn-around. Selective mining is practised, with ore and waste blocks delineated after each blast and before removal to various stockpiles and waste dumps (Table 8). The marginal ore is stockpiled. All ore with grades higher than 0.6 g/t is also stockpiled according to rock type.

Table 5: Navachab Gold Mine pit specifications

	Current	Final
Pit length (N–S strike of MC unit)	900 m	900 m
Pit width (E–W)	375 m	375 m
Pit depth	110 m	220 m
Total t mined	33.3 Mt	54 Mt
Stripping ratio	3.5 : 1	2.62 : 1
Mining rate	4.5 Mt/year	Average 3.9 Mt/year

Table 6: Navachab Gold Mine mining specifications

Haulroad gradient	10%
Haulroad width	20 m
Catchment berm width	15 m
Hanging wall interbench berm width	1.4 m
Footwall interbench berm width	3.0 m
Final hanging wall slope design	56°
Final footwall slope design	53°
Bench height	10 m
Blasthole diameter	102 mm
Blasthole depth	6.0m
Blasthole spacing	3.2 m x 3.0 m

Table 7: Navachab Gold Mine mining contractors major equipment

11	35 ton Caterpillar 769 rear dump trucks
2	4.3 m^3 Liebherr 984 backactor excavator
1	Caterpillar D9 track dozer
1	4.3 m^3 Caterpillar 988 front end loader
1	Caterpillar 824 wheel dozer
1	Caterpillar 149G grader
2	Ingersoll Rand LM500 drill rig
1	Ingersoll Rand LM600 drill rig
3	Gardner Denver RHC5000 drill rig
3	Water carts
2	Water cannon bowsers
2	Bell tractors

Table 8: Navachab Gold Mine stockpiles

Waste	< 0.4 g/t
Mineralised waste	0.4 - 0.6 g/t
Marginal ore	0.6 - 0.8 g/t
Low-grade ore	0.8 - 1.3 g/t
Medium-grade ore	1.3 - 2.8 g/t
High-grade ore	> 2.8 g/t

The primary crusher situated at the stockpile area reduces the ore to minus 200 mm. The ore is then transported to the plant by a 1-km-long conveyor where it is stored in a 3 500 ton silo. A carbon-in-pulp process is used to recover the gold from 110 000 t of ore per month (Fig. 10). Approximately 90% of the gold is recovered, that contained within the maldonite being unresponsive to cyanidisation. The bulk liberation size of the gold is 5 to 10 mm.

The ore is milled to about 78% passing 74 mm. Critical-size pebbles are removed from the mill load and crushed before being returned to the mill feed. The slurry is thickened before being passed through seven leach tanks where it is agitated in a cyanide solution to dissolve the gold according to the reaction:

$$4Au + 8NaCN + O_2 + 2H_2O = 4Na + Au(CN)^{2-} + 4OH^-$$

The slurry is then mixed with granular activated carbon, which adsorbs the gold, in a further series of tanks. The gold-loaded carbon

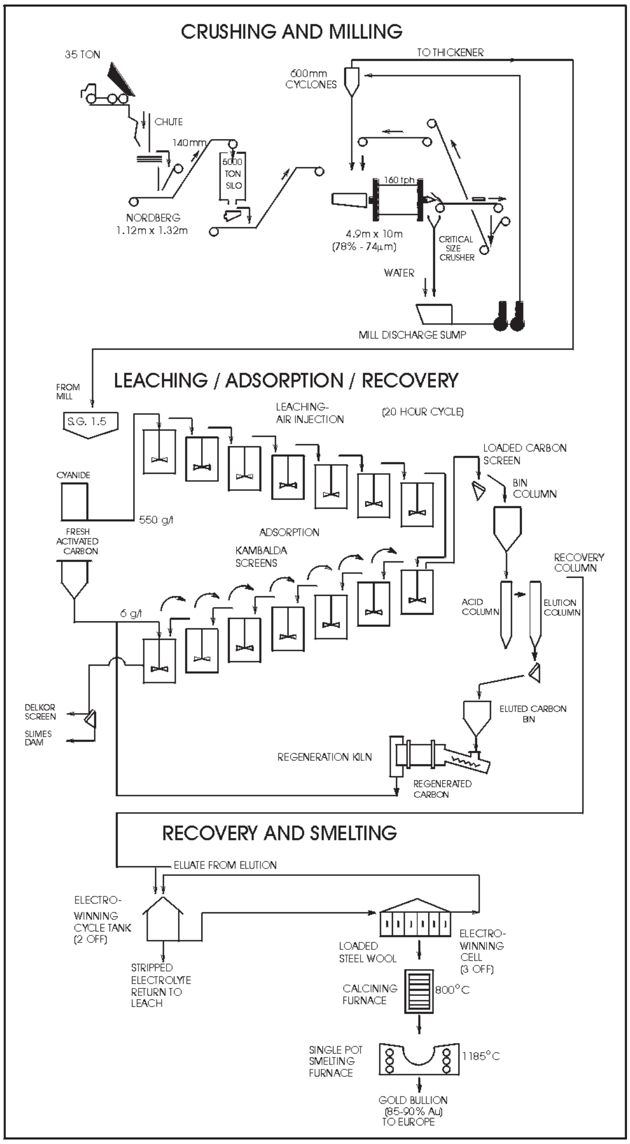

Figure 10: Navachab Gold Mine plant flow sheet (Navachab Gold Mine, 1997)

is separated from the pulp solution and pumped into elution columns. Here it is washed in acid prior to the gold being desorbed by contact with a hot alkaline cyanide solution containing 3% NaCN and 4% NaOH. The dissolved gold is washed from the carbon with hot water at about 120×C.

The pregnant solution is recirculated through two electrowinning cells, operated at approximately 6 V and 18 to 20 A. The gold is deposited on steelwool cathodes. The gold-bearing steelwool passes into a calcining furnace and the calcined gold is then smelted and cast into 22-kg bars, 90% pure. The gold is exported to Switzerland for refining. Approximately 7% silver is recovered as a by-product on refining.

Table 9: Navachab Gold Mine production (Source: Directorate of Mines)

Year	Production (kg)
1989	72
1990	1 453
1991	1 709
1992	1 765
1993	1 781
1994	1 916
1995	1 883
1996	2 145
1997	2 301
1998	1 855
Total	16 880

An environmental management system, based on ISO 14000, was completed in April 1997 and immediately put into effect. Although the focus is on waste and slimes disposal, all mining aspects are covered.

(Information supplied by Navachab Gold Mine, 1997; other references Steven, 1993; Badenhorst, 1993; Badenhorst and Drews, 1993; Steven *et al*., 1994).

3.5.2.3.2 Kransberg South 113 Ooccurrence

Steven *et al*. (1994) reported a distal copper-gold skarn consisting of quartz-chalcopyrite veins in amphibolite facies metacarbonate on the farm Kransberg South 113, 7 km east of Usakos. The mineralisation is found on the edge of a domal structure within northwest-trending fractures. Samples of the pyrometasomatic, stratabound deposit yielded an anomalous value of 11 g/t gold.

3.5.2.4 Arandis Formation - Oberwasser Member

3.5.2.4.1 Otjua -Epako Gold Field, Epako 38

Situated 23 km northeast of Omaruru, the gold field straddles the farms Epako 38 and

Otjua 37. Although the schistose country rock is "shot though with numerous, well exposed, tourmaline-garnet pegmatites, conspicuous quartz blows" and various granites (Haughton *et al*., 1939) these were not found to be auriferous by the miners in the 1930s (Rossouw, 1937). However, deeply weathered grey hornfels lenses within the schist associated with numerous smaller quartz veins (striking N83×E to N138×E, dipping steeply northwards, 5 to 20 cm thick) in the stream beds do contain spongy gold flakes (up to 79 g/t gold). These were mined with the adjacent alluvial gravels from 1937 to 1943, producing 46.9 kg of gold (Miller, 1992b; Steven, 1993; Steven *et al*., 1994). Compare with 3.3.3.2 and 4.7.1.

3.5.2.5 Arandis Formation - Daheim Member

A sericitised and pyritised tuff on the farm Daheim 106, 14 km north of Karibib, was sampled by Petzel (1988b) and yielded anomalous values of 0.95 g/t and >1.0 g/t gold. Although the occurrence is fractured and lenticular veins seem to follow the noses of drag folds, it is thought be volcanogenic in origin (Steven *et al*., 1994).

3.5.2.6 Karibib Formation

3.5.2.6.1 Onguati Mine/Brown Mountain/ Western Workings, Onguati 52

The three small deposits (Onguati, Brown Mountain and Western Workings), situated 15 km north-northwest of Karibib, were last in operation during the 1970s, chiefly for their copper content (Miller, 1992a). See copper chapter for more detail.

Recent investigations have identified "pinch and swell" hydrothermal veins, 0.5 to 2m wide and up to 200 m long at Onguati and Western Workings (Piranjo *et al*., 1991; Piranjo and Jacob, 1991) (see Fig. 11). Gold grades range from 0.1 to 6.0 g/t with peak values of up to 80 g/t (Piranjo *et al*., 1990) associated with copper (1000 ppm), bismuth (up to 300 ppm) and tungsten (up to 140 ppm). The host Karibib Formation marbles have been subjected to medium-grade amphibolite metamorphism associated with granitic intrusions. The sulphide

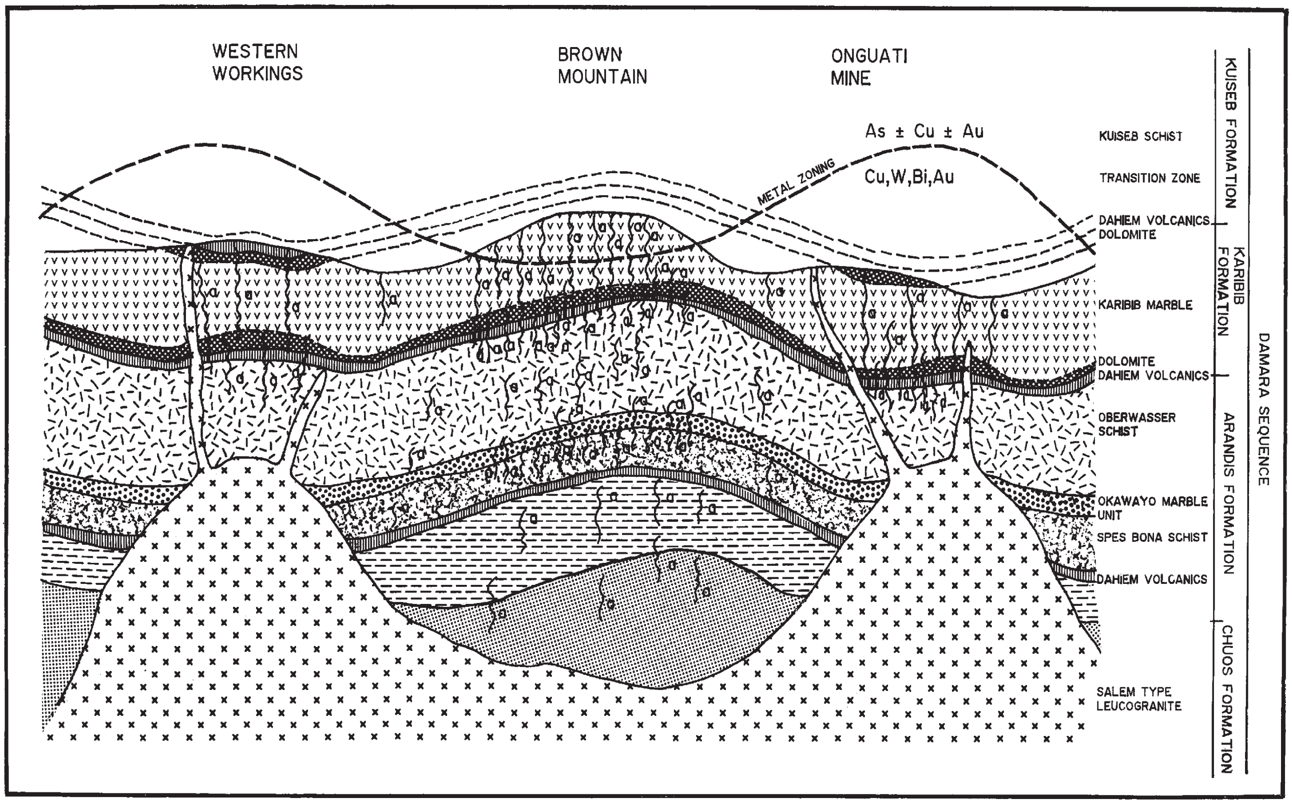

Figure 11: Simplified diagrammatic section, Onguati 52 (Petzel, 1988c)

mineralisation consists of pyrrhotite, chalcopyrite, minor pyrite and arsenopyrite located in fractures within quartz veins, along vein margins and as offshoots into marble host rocks (Petzel, 1988c).

At Brown Mountain, thinner quartz veins form a stockwork with sulphide mineralisation consisting of pyrrhotite, arsenopyrite and minor chalcopyrite. Gold concentrations are erratic with values up to 0.4 g/t associated with arsenic (up to 1000 ppm) and copper (about 250 ppm). No bismuth or tungsten is present. A Gold Fields Namibia Ltd drillhole detected samples with anomalous values of 400 ppb and 2100 ppb gold at a depth of 90 m in quartz veins hosted by altered marbles (Petzel, 1988c; Petzel and Roesener, 1988).

Metal zonation (Cu-Au-Bi-W at Onguati and Western Workings, As-Cu-Au at Brown Mountain) has been reported by Petzel (1988c) and Piranjo *et al*. (1990) as a function of distance from the granitic sources and level of erosion. The shear-hosted quartz vein swarm present in the marbles has been interpreted as a distal gold skarn (Steven, 1993; Steven *et al*., 1994).

Knupp (1989) conducted soil sampling over the farm Onguati 52 obtaining anomalous values of 1716 ppb, > 2000 ppb and 1283 ppb gold, and on Onguati 53 obtaining anomalous values 1694 ppb and > 2000 ppb gold.

3.5.2.6.2 Berger's and Levinson's Claims, Kaliombo 119

Gold nuggets, several millimetres in diameter, occur with chalcopyrite and malachite mineralisation as breccia filling in pegmatite and quartz veins within Karibib Formation marbles on the farm Kaliombo, 35 km east of Karibib. The shear zone parallels the strike of a fold and is about 70 m long and between 1 m to 2 m wide. The maximum concentration of gold from channel samples was 37.75 g/t over 50 cm (Labuschagne, 1976). The deposits are interpreted by Miller (1983a) as being deep-level hydrothermal in origin.

Several other smaller showings of copper oxides, some with gold mineralisation, are known to exist at various localities on the farm within Karibib Formation marbles.

3.5.2.6.3 Mansfeld Mine, Klein Aukas 66

Soil samples collected by Ash (1986) over the old lead-zinc mine, 1 km southwest of Usakos, contained an anomalous value of 130 ppb gold. All other samples contained less than 60 ppb gold. Channel sampling recorded a maximum gold analysis of 19.46 g/t gold over 100 cm. See lead-zinc chapter for more detail.

3.5.2.6.4 Brockman's Claims, Johann Albrechtshöhe 44

Quartz-tremolite pegmatites and veins intruding amphibolite facies metacarbonates at Brockman's claims on the farm Johann Albrechtshöhe 44, 35 km east of Karibib, were investigated by Labuschagne (1976) and found to contain disseminated gold. The gold-skarn mineralisation is found on the edge of a domal structure in northwest-trending fractures. Steven *et al*. (1994) reported grades from the pyrometasomatic stratabound orebody of more than 50 g/t gold.

3.5.2.6.5 Goldkuppe, Otjakatjona 3

The marble-hosted gold mineralisation on the farm Otjakatjona 3, 16 km northeast of Karibib, was mined in 1938 producing 220 g of gold (Anon, 1964). The gold occurs in replacement veins and shears in tremolite marble (Caterall, 1990b). Drill-chip sampling of the stratabound pyrometasomatic deposit assayed at 5.90 g/t, 6.75 g/t and 11.80 g/t gold over 20 m interval (Churchouse, 1987). Compare with 3.3.3.1.6.

3.5.2.6.6 Goldkuppe, Otjimbojo Ost 48

The pyrometasomatic stratabound gold mineralisation (Steven *et al*., 1994), which was investigated by Hoffmann (1988), occurs as quartz-tremolite veins and breccia in an altered marble on the farm Otjimbojo Ost 48, 16 km northeast of Karibib. Subsequent drilling of the gold-skarn deposit produced chip-sampling anomalous values of 1.6 g/t, 2.2 g/t, 2.5 g/t and 3.0 g/t gold (Catterall, 1990b). Compare with 3.3.3.1.5.

3.5.2.6.7 Tsawisis 16

A soil-sample anomaly, 20 km southwest of Usakos, was drilled by AAPSN (Landmark V., 1988c). Best assay values were 0.23 g/t, 0.56 g/t, 0.58 g/t and 0.60 g/t gold.

3.5.2.6.8 Ukuib 84

Hydrothermal veins in Karibib Formation marbles, 40 km southeast of Usakos, were investigated by Mocnik (1973) and De Greef (1988a). A gold grade of 9.0 g/t has been reported.

3.5.2.6.9 Elbe 10

Gold Fields Namibia Ltd investigated the copper-zinc deposits on Elbe 10, 32 km west of Okahandja, in the late 1980s. Deposit A, located in a pyroclastic or sedimentary breccia, was shown to contain 3.291 Mt of ore containing 0.55 g/t gold. The calc-silicate- and marble-hosted Deposit B gossan samples yielded grades varying between 0.8 g/t and 5.7 g/t gold (Corbett, 1988; Petzel, 1989 and 1990a). The syngenetic deposit is thought to have formed through remobilisation by volcanogenic hydrothermal fluids (Greenwood, 1990). See copper chapter for more detail.

3.5.2.6.10 Trekkoppe 120

Grab samples of a siliceous gossan and pegmatite veins, taken 12 km northwest of Trekkoppe Siding, assayed at 0.25 g/t, 0.32 g/t and 0.35 g/t gold, while the best drill-core assay was 0.13 g/t gold (Carr, 1989a; Webb, 1991b).

3.5.2.6.11 Lithium Pegmatite, Habis 71

A gossan containing quartz-malachite veins in tremolite marble on the farm Habis 71, 15 km south of Karibib, was chip-sampled and drilled (Dabrowski and Greenwood, 1988). Anomalous values were 3.0 g/t gold and 1.83 g/t gold over 95 cm respectively.

Steven (1993) and Steven *et al*. (1994) reported that sulphidic quartz-tremolite veins in amphibolite facies metacarbonates at the gold prospect on Habis 71 contained 0.4 g/t gold. The dolomitic marble that drapes a basement inlier hosts the gold-skarn that is thought to be related to red gneissic granite in the core of the dome.

3.5.2.6.12 Occurrences

Grab rock sample results taken by Hoffmann (1988) on the farms Omapyu 75 and Noitgedag 49, approximately 17 km northeast of Karibib, ranged between 0.01 g/t and 0.6 g/t gold. AAPSN also conducted exploration on Omapyu 75 with disappointing results (De Greef, 1988c; Catterall, 1990b).

Structurally controlled quartz veins in fold hinges on the farm Gamikaub 78, 35 km southeast of Usakos, contain an average of 1.0 g/t gold with peaks of 1.2 g/t and 1.75 g/t gold. The stratabound occurrence is thought to be exhalitive in origin (Dekker, 1983; Esterhuisen, 1984; Misiewicz, 1984; Catterall, 1989).

3.5.2.6.13 Anomalies

Sampling of the known copper anomaly on the farm Dorstrivier 15, 40 km south-southwest of Usakos, gave gold peaks of 40 ppb, 87 ppb and 347 ppb gold (Landmark V., 1988a).

A gossanous float of iron-stained quartz veining on Ameib 60, 20 km north of Usakos, was sampled by Ash (1987a). The maximum concentration was 359 ppb gold.

Random rock sampling by Maclaren (1987) in the Namib Lead Mine area, 10 km west of the

Rössing Siding, produced anomalous values of 110 ppb, 113 ppb, 118 ppb and 206 ppb gold.

A magnetite skarn in altered marble on the farm Hakskeen 89, 45 km west of Usakos, contains peaks of 129 ppb and 202 ppb gold in veins and blebs in fold noses (Webb, 1991b).

Gold has been known on Sandamap 64, 32 km west of Usakos, since the 1930s (Schroder, 1932). Steven (1988a) found small gossanous stockworks of fold-related quartz veins in schist to be auriferous. Maximum sample values were 100 ppb, 209 ppb and 360 ppb gold.

A gossan in calcitic marble on Lucasbank 63, 18 km west of Usakos, contained up to 128 ppb, 223 ppb and 415 ppb gold (Steven, 1988b).

Stream-sediment sampling by Gold Fields Namibia Ltd on Spes Bona 105, 15 km north of Karibib, produced anomalous values of 107 ppb, 113 ppb, 120 ppb and 415 ppb gold (Petzel, 1988b).

Anomalous gold values were recorded in Karibib Formation marbles and adjacent Omusema Formation volcanics on the farm Otjozondu 36, 40km southeast of Karibib. A quartz vein within the volcanics assayed 433ppb gold associated with malachite and bornite mineralisation (Petzel, 1989b).

Soil- and stream-sediment sampling by AAPSN in the late 1980s over various farms, situated approximately 40 km south-southwest of Usakos, located the anomalous peak gold values listed in Table 10.

3.5.2.7 Kuiseb Formation

3.5.2.7.1 Sandamap Noord 115

Mineralisation on Sandamap Noord 115, 30 km west of Usakos was investigated by Solar Exploration (Pty) Ltd in the 1930's who trenched the mineralised zone and was first described by Frommurze *et al.* (1942). However, the gold potential of the deposit has only recently been recognised (Steven, 1988a, 1991 and 1993; Petzel, 1990b; Steven *et al*., 1993 and 1994).

The north-northeast trending ferruginous quartz veins, gossan stringers and mylonite rocks on the edge of a D_3/D_4 late-Damaran leucogranite dome are related to the Omaruru and Welwitchia lineaments (see Figs. 12 and 13). The highly altered shear zone is hosted by

Table 10: Karibib Formation Southern Central Zone results (AAPSN)

Farm	Soil sample	Stream-sediment sample	Reference
Hakskeen 89	33, 86 & 97 ppb	-	Stone 1987a and 1987c
Kransberg 59	-	20, 22, 30, 33 & 39 ppb	Knupp, 1989
Northwestern portion of Farm 136	Maximum trace	-	Landmark G., 1987d
Marmor 111	-	Isolated 31 ppb	Landmark V., 1988a
Marmor-Dorstrivier 36	-	Isolated 148 ppb	Landmark V., 1988a
Ukuib West 116	-	Isolated 23 ppb	Landmark V., 1988a
Eastern portion of Vredelus 112	-	All < 20 ppb	Landmark V., 1988a; De Greef, 1988a
Etusis 75	-	17, 23, 77 & 259 ppb	Landmark G., 1987a
Kubas 77	-	All < 10 ppb	Landmark G., 1987a
Ovikenga 78	-	Bulk peaks 44 & 45 ppb	De Greef, 1988c
Dobberstein's Claims, Gamikaub 78	-	Bulk high 0.4 ppb	De Greef, 1988c
Rössing Mine Area	-	0.27 ppb	Landmark G., 1988a
Karibib Townlands 57	-	20, 21, 25, 49 & 50 ppb	Marsh, 1986

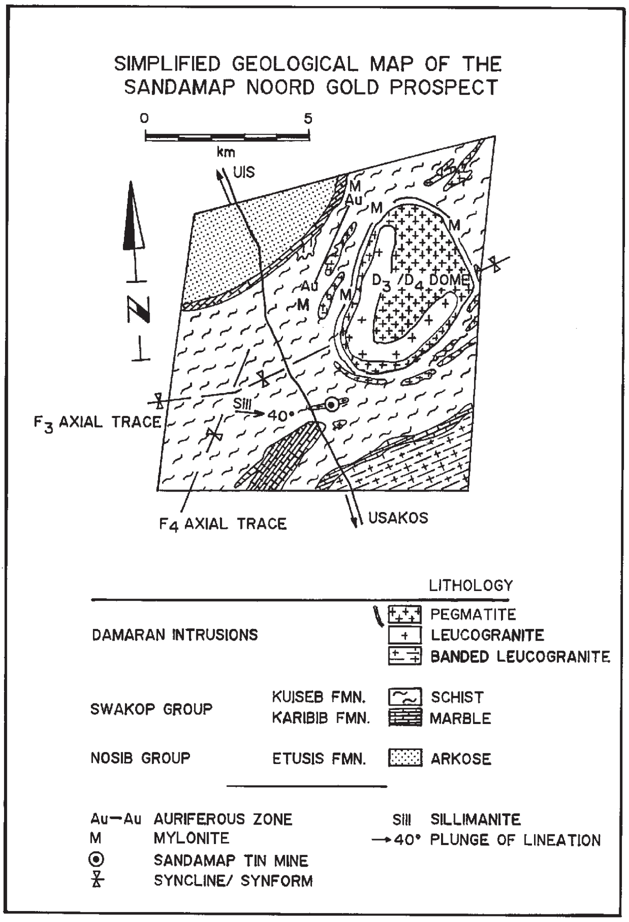

Figure 12: Simplified geological map, Sandamap Noord (after Steven, 1993)

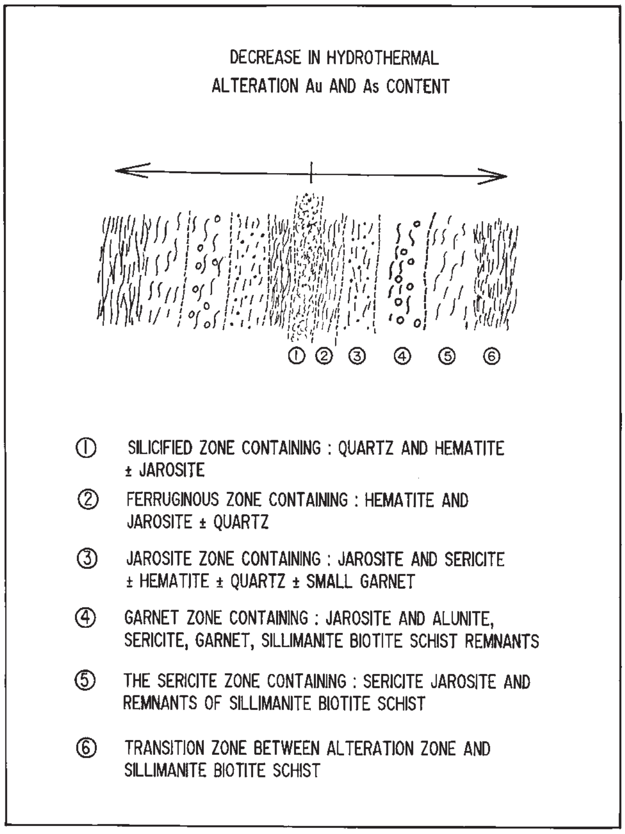

Figure 13: Detail of shear zone, Sandamap Noord (Steven, 1988a)

upper amphibolite metamorphic facies metaturbidites. Ore minerals are native gold, loellingite, arsenopyrite, pyrrhotite, pyrite and galena with garnet, grunerite, tourmaline, graphite, calcite, kaolinite, alunite, jarosite and brookite as gangue minerals. Although no volcanic rocks have been identified in the vicinity, syntectonic granite occurs adjacent to the mineralised structure and late-/post-tectonic cassiterite-bearing pegmatites occur within 1 km of the gold occurrence.

Steven *et al*. (1994) provisionally classified the deposit as turbidite-hosted gold of magmatic origin with auriferous fluids concentrating in high-strain zones.

Sampling yielded maximum concentrations of 4.06 g/t, 4.90 g/t, 18.60 g/t and 45.80 g/t gold. Reserve are estimated as 240 000 t grading at 5 g/t gold.

3.5.2.7.2 Occurrences

Steven *et al.* (1994) reported that gossanous quartz veins concentrated in kink bands in amphibolite facies metaturbidites on the farm Okawayo 46, 10 km northeast of Karibib, contained up to 10 g/t gold.

Stream-sediment sampling by AAPSN over the western portion of Otjimbingwe Reserve 104, 20 km south of Karibib, yielded disappointing results with all samples assaying below 20 ppb gold (Landmark G., 1987e). However, a grab-rock sample did contain 1.27 g/t gold (De Greef, 1988a).

Catterall and Freyer (1990) stream-sampled a portion of the farm Otjimbojo West 42, 28 km northeast of Karibib. The best anomaly found was 46.7 ppb gold. The best grab-rock sample result was 29.8 g/t gold.

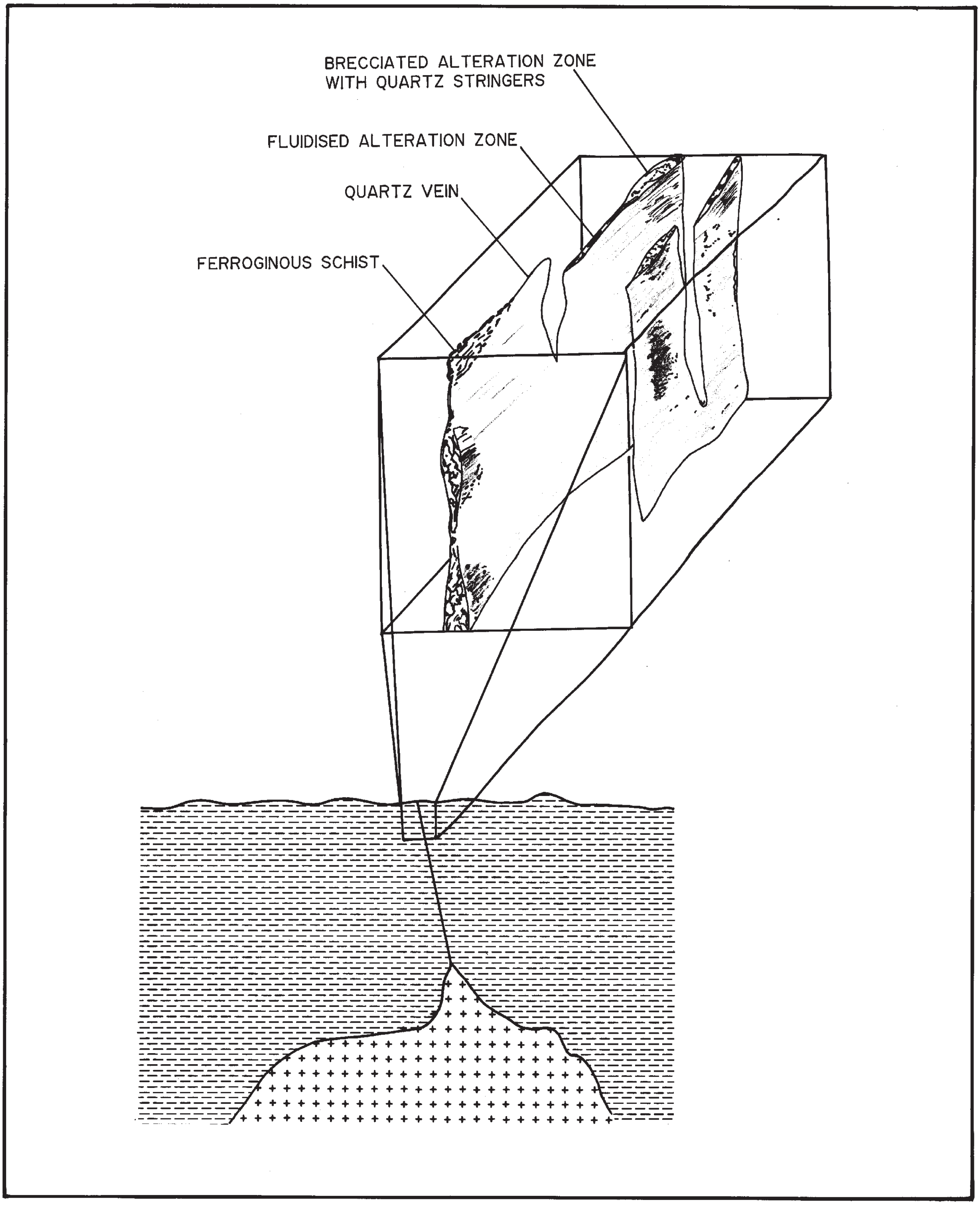

Figure 14: Schematic block diagram of mineralised zone morphology, Sandamap Noord (Petzel, 1990b)

3.5.2.7.3 Anomalies

Stream-sediment sampling, with some soil sampling, by AAPSN over Kuiseb Formation rocks on various farms in the Karibib District detected several gold anomalies (see Table 11).

Similarly, exploration work done by Namex (Pty) Ltd to the north of Omaruru found several anomalies which are given in Table 12.

A sampling maximum value of 0.52 g/t gold was recovered from discordant lenses of

Table 11: Kuiseb Formation Southern Central Zone gold results (AAPSN)

Farm	Anomaly	Reference
Northwest portion of Audawib West 81	High 23 ppb, rest < 20 ppb	Landmark G., 1987e
Toanib Süd 117	High 21 ppb, rest < 20 ppb	Landmark G., 1987e
Portion of Neu Schwaben 73	All < 20 ppb	Landmark G., 1987e
Portion of Tsaobismund 85	Peaks 11, 12, 17 22 & 35 ppb	De Greef, 1988b
Portion of Rooikuiseb 109	Peaks 12 & 22 ppb	De Greef, 1988b
Portion of Horebis Süd 108	Peaks 12 & 13 ppb	De Greef, 1988b
Karibib 54	Peaks 21 & 39 ppb	Landmark G., 1988b
Brabant 168	High 0.47 ppb, soil 905 ppb	Landmark V., 1989
Erongorus 166	High 0.20 ppb	Landmark V., 1989

Table 12: Kuiseb Formation Southern Central Zone gold results (Namex (Pty) Ltd)

Farm	Stream sediment	Reference
Portion of Goabeb 63	Highs 86, 96 & 106 ppb	Schauer, 1988
Portion of Lindholm 63	Highs 58, 60, 63, 65, 68 & 70 ppb	Carr, 1989c
Portion of Omaruru Townlands 85	High 205 ppb	Carr, 1989c
Portion of Kakombo 90	Highs 67, 70, 80, 90, 98 & 273 ppb	Carr, 1989c

tourmaline-quartz replacement veins in an amphibolite-facies quartzitic metaturbidite on the farm Hakskeen 89, 50 km west of Usakos (Steven, 1993; Steven *et al*., 1994). The zone of tourmalinisation parallels the Welwitchia lineament and is thought to be related to mid- to late-Damaran pegmatites.

A podiform skarn with quartz stringers in calcitic marble, 1.5 m wide and with a 300 m strike length, was sampled by Holman (1987b) on the farm Ketelbank 66, 50 km northwest of Usakos. The values obtained range between 0.2 g/t to 0.73 g/t gold.

3.5.2.8 Undifferentiated

Carbonate-hosted sulphides on the farm Erindi 58 some 75 km northwest of Okahandja were drilled by Newmont South Africa Limited (1975) and Rossing Uranium Ltd (Hart,1993). Maximum assay values were 10.38 g/t, 30.85 g/t and 38.9 g/t gold. The stratabound deposit has been interpreted as having a pyrometasomatic origin.

3.5.3 Nosib/Swakop Groups

3.5.3.1 Undifferentiated

Stone (1987b) obtained an anomalous value of 45 ppb gold from stream-sediment sampling on Vergenoeg 92 and 12 ppb gold from two adjacent soil samples on Trekkoppe 120. Both farms are some 50 km southwest of Usakos.

3.6 Northern Central Zone

3.6.1 Nosib Group

3.6.1.1 Khan Formation

Rock-chip sampling of quartz-limonite veins in a quartz-graphite-biotite schist on the farm Uithou 87, 60 km northwest of Usakos, returned maximum concentrations of 165 ppb, 172 ppb and 182 ppb gold (Carr and Smalley, 1988c).

3.6.2 Swakop Group

3.6.2.1 Karibib Formation

Gold panning on claims on Epako 38, 30 km north of Omaruru, showed visible gold (Rossouw, 1937; Martin, 1965). Stream-sediment sampling by AAPSN detected anomalies of 30.8 ppb and 329 ppb gold (Landmark V., 1988b; Catterall, 1990a). Compare with 3.3.2.3.1 and 4.71.

Stream sampling on Epako Süd 39, 30 km north of Omaruru, produced an anomalous value of 78.6 ppb gold (Catterall, 1990a).

Haughton *et al.* (1939) described a pegmatite associated with a skarn in calc-silicate-marble on Tjirundo 91, 30 km north of Omaruru, as being auriferous. Stream-sediment sampling yielded a maximum value of 24.1 ppb gold (Catterall, 1990a). See tin chapter for more detail.

On Tjirundo Süd 149, 30 km north-northwest of Omaruru, Haughton *et al*. (1939) noted small, scattered specks of gold in vein-quartz reef in grey tourmaline granite with visible gold occurring in limonite-rich cavities.

Petzel (1988a) sampled sideritic veins in quartzite on Etendero 95, 25 km north of Omaruru, recording maximum concentrations of 44 ppb and 62 ppb gold. Rock samples of tungsten-bearing skarns on farms situated some 25 km north of Omaruru gave the following anomalous values: 92 ppb gold on Otjipetekera Süd 97, 55 ppb gold on Okangue 94 and 65 ppb, 88 ppb and 93 ppb gold on Schonfeld 92.

Rock-chip sampling by Carr and Smalley (1988a and 1988b) on Marenica 114, 75 km west-northwest of Usakos, gave anomalous values of 138 ppb, 147 ppb, 165 ppb, 190 ppb and 215 ppb gold.

3.6.2.2 Kuiseb Formation

3.6.2.2.1 Anomalies

A few minute specks of gold were found in the mineralised greisenised selvages of a pegmatite vein in the Paukuab/Baukwab area, 67 km west of Omaruru (Haughton *et al.*, 1939; Anon, 1967).

3.7 Northern Zone

3.7.1 Nosib Group

3.7.1.1 Undifferentiated

Soil sampling over Farm 485, 33 km west of Khorixas, produced assay results ranging between 2.8 ppb and 24.8 ppb gold (Marsh *et al.*, 1989).

3.7.2 Swakop Group

3.7.2.1 Karibib Formation

3.7.2.1.1 Lost Valley occurrence, Landeck 77

Rock and soil sampling over the Lost Valley copper anomaly on the farm Landeck 77, 70 km west of Outjo, produced peaks of 2.0 g/t and 10 ppb gold respectively (Marsh, 1989b).

3.7.2.1.2 Saturn 103 Anomaly

Anomalous values of 0.80 ppb and 0.93 ppb gold were detected by Marsh (1989b) during stream-sediment sampling on Saturn 103, 70 km west of Outjo.

3.7.2.1.3 Okorusu 499 Anomaly

Copper-gold skarn mineralisation was sampled by Petzel (1995) on Okorusu 499, 25 km south of Otavi. Rock samples contained 108 ppb, 471 ppb and 7845 ppb gold.

3.7.3 Kuiseb Formation

3.7.3.1.1 Ondundu-Otjiwapa Gold Field

This gold field, situated 90 km northwest of Omaruru, was discovered in 1917. However, production only commenced in 1924 (De Kock, 1934b). The bulk of production came from alluvial and eluvial workings between 1924 and 1927 (Anon, 1926 and 1927; Storey, 1946; see also 4.7.2.), but limited underground mining was carried out between 1930 and 1939 on free-milling oxidised ores at shallow depths (Anon, 1962; Martin, 1965). Between 1924 and 1945, production of unrefined (up to 1934) and later refined gold totalled 617.34 kg (see Table 13) from both alluvial/eluvial and hard-rock mining (Anon, 1964 and 1967).

The gold-bearing quartz-feldspar veins that occur parallel to bedding planes of greenschist facies metaturbidites (impure phyllite and quartz-mica-feldspar schist) are confined to a 10 km^2 area where intense folding occurs (Steven *et al.*, 1994) (Fig.15). A series of tight synclines and anticlines plunges 30^{o} to the south (Thomas, 1932) (Fig. 16). Two generations of quartz veining have been identified by Storey (1946). The older, and most prevalent, consists of greasy grey quartz which contains good gold grades.

Table 13: Production figures, Ondundu gold field (Source: Directorate of Mines)

Year	Production (kg)
1924	4.577
1928	16.843
1929	13.552
1930	6.905
1934	38.543
1935	64.154
1936	68.528
1937	61.499
1938	51.305
1939	48.323
1940	38.723
1941	7.353
1942	7.230
1943	5.266
1944	3.298
1945	2.815
1946	2.261
1948	0.585
1950	0.933
1962	5.724
1963	0.087
Total	448.504

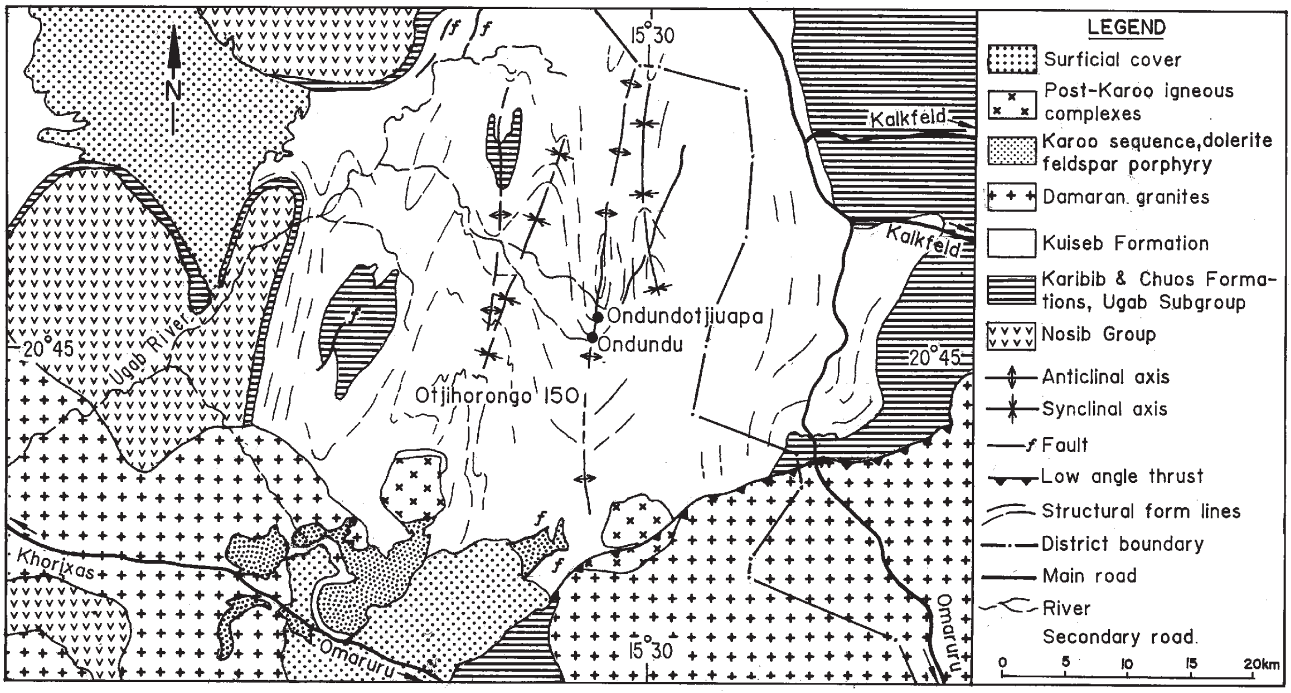

Figure 15: Generalised geological map of the Ondundu area (Geological Survey of Namibia)

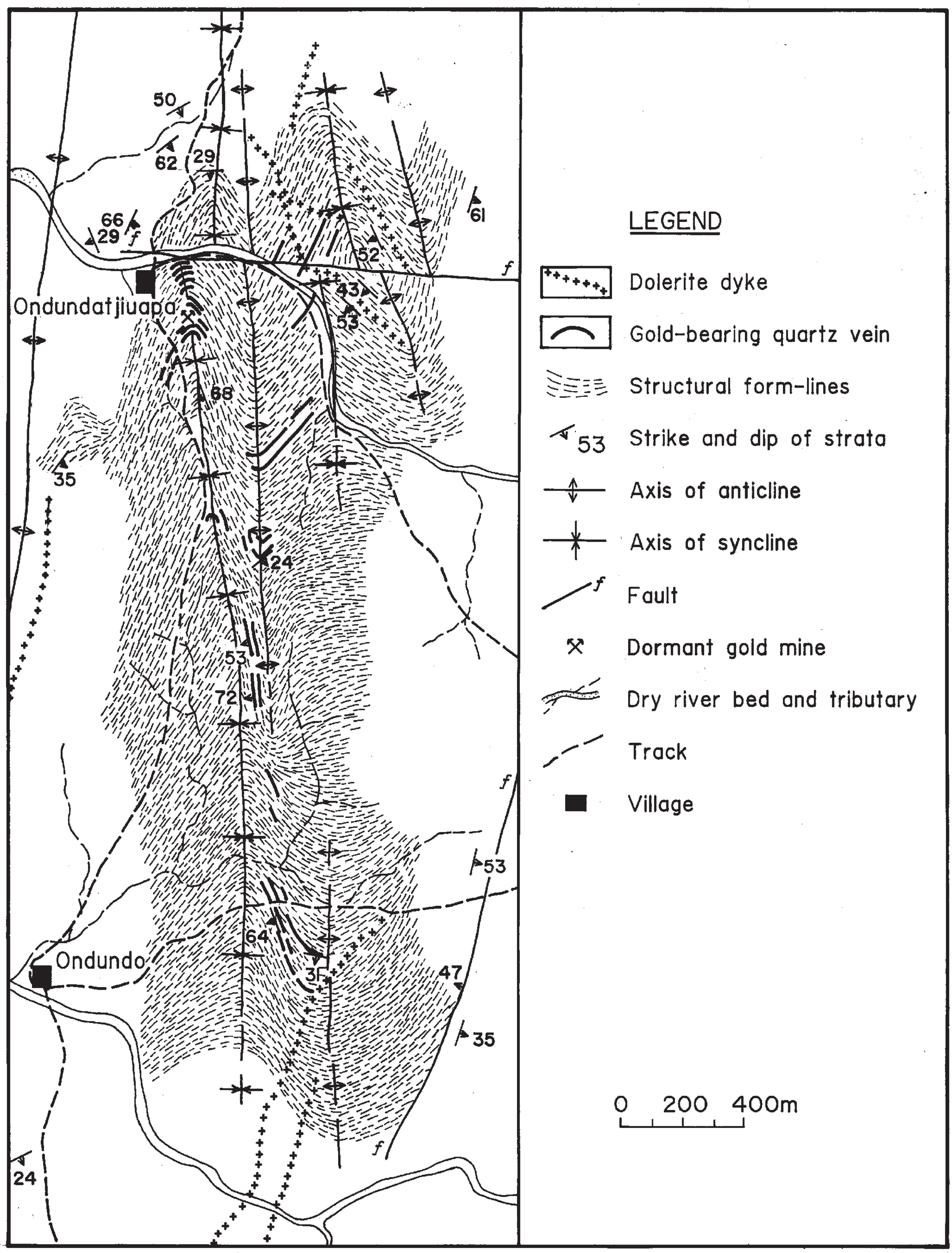

Figure 16: Detailed geological map of the Ondundu gold fields (after Reuning, 1925)

The younger glassy white quartz is barren or contains only traces of gold and occurs only in isolated patches. Reuning (1937) described a third, crosscutting style of veins and veinlets.

Auriferous quartz veins contain calcite, siderite, pyrite and marcasite of hydrothermal origin and are up to 61 cm wide and 100 cm long (Cooke, 1965a).

Table 14: Kuiseb Formation Northern Zone results (AAPSN)

Farm	Stream-sediment sampling maximum values
Kleinfontein 488	8.0, 12.0, 22.0 & > 40.0 ppb
Kaokokroon 487	13.3, 20.7, 20.7 & >35.1 ppb
Korechas 381	2.67, 8.0, 32.9 & 33.53 ppb

Grades of 4.44 g/t to greater than 14 g/t with an average of 5.8 g/t gold have been reported (Reuning, 1937). Reserves have been calculated at 4.2 Mt at 3.21 g/t gold in country rock, with a further 800 000 tons in quartz veins at a grade of 17.01 g/t gold.

3.7.3.1.2 Anomalies

Steven *et al*. (1994) have recorded anomalous values of up to 0.58 g/t gold from discordant quartz-tourmaline veinlets in amphibolite facies metaturbidite 10 km east of the Messum mountains. The pyrite, scheelite and bismuth sulphide mineralisation is concentrated in kink bands. The tourmaline alteration is thought to be related to the intrusion of late-Damaran granites and pegmatites.

Marsh (1989b) conducted stream-sediment sampling on the farms Hankow 78 and Landeck 77, 70 km west of Outjo. Peak values of 0.60 ppb and 1.33 ppb gold were recorded on Hankow 78, and values of 1.00 ppb, 1.07 ppb and 5.33 ppb gold were recorded on Landeck 77.

Marsh *et al*. (1989) sampled stream sediments to the east of Khorixas. The maximum gold concentrations are given in Table 14.

3.7.4 Mulden Group

3.7.4.1 Undifferentiated

3.7.4.1.1 Narachaams/Petrusfontein Occurrence

A sample of quartz veining in sandstone taken by the Solar Development Company in the Narachaams/Petrusfontein area, 18 km west of Fransfontein village, contained 43.54 g/t gold (Schroder, 1932).

3.7.4.1.2 Anomalies

Gold is reportedly present on Fransfontein 6, 5 km west of the settlement (Anon, 1967). Stream-sediment sampling on Austerlitz 515, 56 km west of Khorixas, produced anomalies of 2.33 ppb and 4.00 ppb gold (Marsh, 1989a). Anomalies of 7.46 ppb, 9.33 ppb and 82.6 ppb gold were found on the farm Navarre 383, 4 km east-northeast of Khorixas (Marsh *et al*., 1989).

3.8 Southern Kaoko Zone

3.8.1 Swakop Group

3.8.1.1 Amis River Formation

Anomalous values of 129 ppb, 145 ppb, 150 ppb and 160 ppb gold were obtained by Lyons (1986) from an altered ferrugenous, siliceous and brecciated shear zone on the farm Probeer 535, 78 km southwest of Khorixas.

3.9 Central Kaoko Zone

3.9.1 Nosib Group

3.9.1.1 Undifferentiated

A grab sample from a gossanous quartz-barite vein in the Oruwanje area, 80 km north-northwest of Sesfontein, contained 2.38 g/t gold (Ransom, 1982; Collins, 1985).

Channel sampling of quartz veins in a quartz-biotite schist at the EM 1913 BC occurrence, 13.5 km west of Sesfontein, produced results of 4.95 g/t gold over 2 m and 16.3 g/t over 1 m (Land, 1991).

3.9.2 Swakop Group

3.9.2.1 Chuos Formation

In the Otwane area, 40 km north-northeast of Sesfontein, Ransom (1982) obtained an assay result of 0.3 g/t gold from a hydrothermal quartz vein.

3.10 Eastern Kaoko Zone

3.10.1 Mulden Group

3.10.1.1 Sesfontein Formation

Erongo Mining & Exploration Company Ltd detected the EM 1913 BD/1 (4.84 ppb & 15.5 ppb gold) anomaly, 35 km southeast of Sesfontein, and the EM 1913 BC/2 (2.99 ppb and 8.10 ppb gold) anomaly, 20 km south-southwest of Sesfontein, during a stream-sediment sampling programme over an area 25 km south of Sesfontein.

3.11 Northern Platform

3.11.1 Nosib Group

3.11.1.1 Askevold Formation

3.11.1.1.1 Eenberge Deposit, Driekoppies 801

Mineralisation in hydrothermally altered acid volcanics at Eenberge on the farm Driekoppies 801, situated 10 km south of Kombat, was drilled by Falconbridge with results of 0.22 ppm and 0.56 ppm gold (Blaine, 1974). See copper chapter for more detail.

3.11.2 Hakos Group - Kudis Subgroup

3.11.2.1 Undifferentiated

Grab samples taken from a hematite-rich quartz plug/blow on Egue 578, 30 km south of Otavi, gave a peak value of 0.6 g/t gold (Marsh, 1985).

3.11.3 Otavi Group - Abenab Subgroup

3.11.3.1 Berg Aukas Formation

3.11.3.1.1 Saltzbrunnen Deposit, Rietfontien 344

A fault zone on the contact between the Nosib Group and Abenab Subgroup, known as the Saltzbrunnen deposit on the farm Rietfontien 344, 10 km south of Kombat, was drilled by Falconbridge Exploration (Pty) Ltd. Sampling of drillcore revealed 0.40 g/t gold over 7 m (Blaine, 1974).

3.11.3.2 Undifferentiated

Erongo Mining & Exploration Company Ltd conducted an exploration programme to the north of Opuwo where several gold prospects showed promise (Table 15).

Table 15: Abenab Subgroup, Northern Platform results (Erongo Mining & Exploration Company Ltd)

Prospect	Host lithology	Best result	Reference
Na - 31	Pyritic black shales	Drillcore; 2 ppb	Knupp, 1995
Chiruumbu	Quartz/sparry dolomite-filled fissures	Rock 1.35 g/t	Freyer *et al*., 1993; Freyer & Knupp, 1995
Ovithema	Quartz fissures in dolomite and dolomitic shale	Rock 124 ppb	Freyer *et al*., 1993
Otumbuiti	Pyritic quartz fissures in dolomitic shale	Rock 149 ppb	Freyer *et al*., 1993
Elephant	Goethite float	Rock 19 g/t	Freyer & Knupp, 1994
Elephant	Pink dolomitic limestone	Rock 0.3 g/t	Freyer & Knupp, 1994

Table 16: Salem Granite results (AAPSN)

Farm	Soil sampling	Stream-sediment sampling	Reference
Western portion of Vredelus 112	Maximum trace	-	Landmark G., 1987d
Geluk 116	Maximum trace	-	Landmark G., 1987d
Okamahoro 19	Maximum trace	-	Churchouse, 1987
Portion of Omapyu Süd 77	-	Bulk peak value - 37 ppb	De Greef, 1988c & d
Portion of Otjakatjongo 3	-	Bulk peak value - 0.13 ppb	De Greef, 1988d

3.11.4 Tsumeb Group

3.11.4.1 Hüttenberg Formation

3.11.4.1.1 Tsumeb Mine, Tsumore 761

This well-known polymetallic sulphide deposit contains an average of 10 ppb gold with certain high-grade areas containing 280 ppb to 300 ppb gold (Lombaard *et al*., 1986). See copper chapter for more detail.

3.11.4.2 Undifferentiated

Rock samples of quartz and sparry dolomite filled fissures near Otjiurunga, 32 km north of Opuwo, contained a maximum of 17 ppb gold (Freyer *et al*., 1993).

3.12 Syn-Damara Intrusions

3.12.1 Goas Diorite

All stream-sediment samples taken over the southeastern portion of the farm Goas 79, 20 km south of Karibib, contained less than 20 ppb gold (Landmark G., 1987e).

3.12.2 Salem Granite

AAPSN exploration programmes undertaken over farms underlain by Salem Granite in the Karibib and Okahandja Districts produced the results given in Table 16.

4. Gold Occurences in Post-Damaran Rocks

4.1 Bremen Granite

Metasomatic alteration of the pipe/plug breccia filling at the Ai-Ais Lead Mine on the farm Kanabeam 331, 12 km south of the Ai-Ais Resort, which was previously mined for silver, lead and zinc, contains very minor amounts of gold (20 ppb) (Johnston, 1983; Hartleb, 1985; Von Berkel, 1986). See silver, lead and zinc chapters for more detail.

4.2 Karoo Sequence - Whitehill Formation

Structurally controlled gold mineralisation on the farm Grauhof 147, 35 km northeast of Keetmanshoop, was first detected by soil-sampling anomalies of 36 ppb and 100 ppb gold. Subsequent drilling confirmed stratabound hydrothermal gold mineralisation with assay values up to 6.47 g/t gold (Webb, 1991a).

4.3 Syn-Karoo Intrusives?

A composite basic dyke, known as the Homestead Dyke, comprising mainly gabbro and syenite, cuts metasedimentary units of the Ugab Subgroup on the farm Homestead 205, 36 km north of Otjiwarongo. Percussion drilling has been done to test magnetic and geochemical anomalies. Although assayed for, no gold was detected (Veldsman, 1976). See copper chapter for more detail.

Table 17: Erongo Caldera results (Roesener, 1988a)

Farm	Host lithology	Selected maximum values
Niewoudt 151	Mafic dyke and quartz-tourmaline pegmatites	90, 100, 136 & 143 ppb
Niewoudt 186	Propyllic altered basalt	75, 77 & 78 ppb
Ombu 130	Tourmaline breccia in argillic altered diorites	44, 51, 56, 56 & 71 ppb
Ekuta 129	Hydrothermal veins in metasomatised tuff	433, 522 & 532 ppb
Omaruru Townlands 85	Quartz-feldspar-tourmaline pegmatites	468, 512, 594 & 606 ppb
Eileen 164	Pegmatite in epidotised and chloritised basalt	51, 76 & 83 ppb

4.4 Erongo Granites

Gold Fields Namibia Ltd investigated the gold potential of the Erongo Caldera (Roesener, 1988) to the southwest of Omaruru. Selected sampling maximum concentrations are given in Table 17. It should be noted that certain assay results are considered to be unreliable.

Piranjo (1990) mentions traces of gold (up to 100 ppb) that occur locally in fumarolic altered ash-flow tuff rocks on the farm Ekuta 129, 12 km southwest of Omaruru.

Reconnaissance sampling by AAPSN detected a stream-sediment sampling anomaly of 2.07 ppb gold and a soil-sampling anomaly of 66 ppb gold on Omandumba Ost 133, 30 km west of Omaruru (Landmark V., 1989).

A stockwork of brecciated veins and propyllic altered basalt within Kuiseb Formation metasediments on Niewoudt 151, 17 km southwest of Omaruru, has been investigated by both Gold Fields Namibia Ltd (Roesener, 1988a) and AAPSN (Marsh, 1990). Soil-sampling anomalies obtained were 70 ppb, 72 ppb, 79 ppb and 92 ppb gold.

4.5 Brandberg Granite Complex

Piranjo (1987) investigated a fossil hot-spring system in the Numas Valley on the farm Erongorus 166, 150 km west of Omaruru. Rock samples taken contained 0.11 g/t, 0.12 and 0.2 g/t gold.

4.6 Paresis Igneous Complex

Metosomatically altered basaltic dykes on Naribes 166, 30 km southeast of Outjo, returned anomalous values of 153 ppb, 160 ppb and 210 ppb gold (Roesener, 1988b).

4.7 Brukkaros Dykes

Samples of a quartz-barite vein on Bersheba Reserve 170, 95 km north-northwest of Keetmanshoop, contained only traces of gold (Von Berkel, 1985).

4.8 Quaternary Deposits

4.8.1 Alluvial Deposits

4.8.1.1 Epako-Otjua Alluvial Gold Field

Alluvial gold was mined from several small dry river courses on Epako 38 and Otjua 37, 25 km north-northeast of Omaruru, between 1937 and 1943. A total of 43.54 kg of gold was produced, mainly from one-man operations (Anon, 1967). The gold is associated with corundum in the gravels and is thought to be derived from numerous small quartz veins within the mica schist country rock, striking east–west and dipping steeply to the north, adjacent to the stream beds (Haughton *et al.*, 1939). Some flakes and nuggets of gold are well rounded, whereas others are spongy in appearance (Anon, 1967). Compare with 3.3.2.3.1 and 3.3.3.2.

Table 18: Namibian gold production since 1924 (Source: Mining Directorate)

Year	Production (kg)	Year	Production (kg)
1924	4.577	1965	31.166
1928	16.843	1977	70.000
1929	13.552	1978	172.000
1930	6.905	1979	55.300
1934	39.134	1980	25.810
1935	108.775	1981	31.210
1936	137.916	1982	242.000
1937	95.161	1983	296.000
1938	60.937	1984	196.000
1939	50.369	1985	194.000
1940	42.227	1986	184.000
1941	9.444	1987	172.000
1942	7.200	1988	240.000
1943	5.266	1989	336.000
1944	3.298	1990	1 605.000
1945	2.815	1991	1 850.000
1946	2.261	1992	2 030.000
1947	0.222	1993	1 950.000
1948	15.211	1994	2 450.000
1949	1.120	1995	2 099.000
1950	0.933	1996	2 145.000
1962	5.724	1997	2 417.000
1963	0.087	1998	1 882.000
1964	0.991	Total	21 304.450

4.8.1.2 Ondundu-Otjiwapa Alluvial Gold Field

This field was the site of what has been termed the only "true" Namibian gold rush, which took place between 1924 and 1927. The Ondundu-Otjiwapa gold field, situated 90 km northwest of Omaruru, produced 614.4 kg of gold between 1924 and 1963, mainly from alluvial/eluvial sources, although some hard-rock mining between 1930 and 1939 also contributed to the total (see 3.3.4.5.1.).

4.8.1.3 Other Alluvial Occurrences and Anomalies

Very sparsely distributed fine gold and small nuggets (maximum 6 mm) were recovered from alluvial cassiterite workings in the Neineis/Nainais area, 90 km west of Omaruru (Haughton *et al*., 1939; Anon, 1967). Production between 1941 and 1942 was 15.24 kg (Anon, 1964).

Finely disseminated gold was also found in alluvium from which cassiterite was recovered on Neubrand's Claims on the farm Pritzelwitz 128, (also known as Kransberg), 18 km southwest of Omaruru (Haughton *et al*., 1939; Anon 1967).

Bürg (1942) mentioned several drainage courses that were investigated for their precious metal content at the turn of the century. None of these, however, proved to have more than traces of gold.

5. Production

Namibian gold production since 1924 is given in Table 18.

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