Table 3.2

Estimates of South Africa's historical production of the PGM, 1926–1992 (kg)

Period		Individual annual data for the five-year period						Annual growth/ decline, %
		1	2	3	4	5	Mean	
1925–29		–	328	609	736	927	650	+39,18
1930–34		1 721	1 467	288	74	1 174	945	–31,28
1935–39		973	1 024	1 232	1 660	1 714	1 321	+17,53
1940–44		1 863	2 036	2 116	2 028	2 556	2 120	+ 6,49
1945–49		2 094	1 985	2 013	2 310	3 366	2 354	+11,64
1950–54		4 486	5 938	7 232	9 305	10 713	7 535	+24,49
1955–59		11 873	15 072	18 777	9 331	11 644	13 339	– 5,05
1960–64		12 638	10 886	9 331	9 331	18 622	12 162	+ 6,41
1965–69		23 328	33 780	25 261	26 142	29 719	25 646	+ 5,96
1970–74	Pt	28 708	23 962	26 580	44 117	53 944	35 462	+20,59
	Pd	12 130	10 145	11 222	19 557	22 791	15 169	+21,14
	Ru	3 888	3 237	3 608	6 249	7 277	4 852	+21,06
	Rh	1 431	1 198	1 377	2 327	2 725	1 812	+21,56
	Ir	498	395	498	829	960	636	+22,80
	Os	249	198	234	389	388	292	+16,91
	PGM	**46 904**	**39 135**	**43 519**	**73 468**	**88 085**	**58 223**	**+20,81**
1975–79	Pt	49 821	52 077	55 700	60 154	57 982	55 147	+ 4,58
	Pd	21 060	21 886	23 555	23 203	25 709	23 083	+ 4,68
	Ru	6 673	7 057	7 557	6 982	6 460	6 963	– 1,01
	Rh	2 530	2 637	2 827	2 612	2 416	2 604	– 1,01
	Ir	885	932	989	913	845	911	– 1,02
	Os	406	424	454	426	388	418	– 1,00
	PGM	**81 465**	**84 997**	**91 082**	**9 284**	**93 800**	**89 126**	**+ 3,93**
1980–84	Pt	55 811	55 986	54 106	58 329	66 885	58 223	+ 4,11
	Pd	28 216	28 305	22 737	22 261	28 748	26 053	– 2,01
	Ru	8 716	8 793	5 684	5 974	7 598	7 353	– 6,40
	Rh	2 346	2 367	1 942	2 085	2 640	2 276	+ 1,10
	Ir	905	913	582	620	792	762	– 6,33
	Os	336	338	194	197	293	272	– 7,81
	PGM	**96 330**	**96 702**	**85 245**	**89 466**	**106 956**	**94 939**	**+ 1,97**
1985–89	Pt	75 156	73 530	78 353	80 591	80 402	77 606	+ 2,29
	Pd	32 440	32 542	33 891	34 518	35 291	33 736	+ 2,30
	Ru	9 475	9 105	9 856	10 620	11 600	10 131	+ 5,75
	Rh	3 309	4 098	4 509	4 623	4 911	4 290	+ 9,53
	Ir	995	939	1 026	1 030	1 110	1 020	+ 3,16
	Os	353	328	345	340	370	347	+ 1,31
	PGM	**121 728**	**120 542**	**127 980**	**131 722**	**133 684**	**127 130**	**+ 2,08**
1990–92	Pt	85 846	86 157	91 830	–	–	87 944	+ 3,43
	Pd	38 257	39 501	43 314	–	–	40 357	+ 6,40
	Ru	11 094	10 194	9 948	–	–	10 412	– 5,31
	Rh	5 219	5 634	6 458	–	–	5 770	+11,24
	Ir	1 116	1 026	1 001	–	–	1 048	– 5,29
	Os	381	349	340	–	–	357	– 5,53
	PGM	**141 913**	**142 861**	**152 891**	**–**	**–**	**145 888**	**+ 3,80**
South African export sales								
1980–84		n.a.	n.a.	98 159	103 499	112 547	104 547	+ 7,08
1985–89		118 094	120 433	130 171	130 854	137 278	127 366	+ 3,92
1990–1992		135 581	141 120	137 063	–	–	137 921	+ 0,55

n.a. = Information not available

copper, and 2,49 g/t of 'precious metals'. Grades were later reported as 4,5 per cent nickel, 2,45 per cent copper, 0,56 g/t osmium, and 0,47 g/t palladium. However, the latest ISMI report (Sutphin and Page, 1986) suggested reserves of 10 Mt at a grade of 2,5 g/t PGM (1981) and a production rate of 2,025 Mt/y. As was pointed out in Section 2.2, at that rate the deposit would have been exhausted by this time. There are, however, many Pechanga/Monchegorsk type intrusions in the area, but they will take time to explore and develop.

I now turn to the most important productive PGM deposits of the Noril'sk and Talnakh areas inside the Arctic circle in Siberia, which were dealt with in some detail in Section 2.2. The first deposit to be discovered was at Mount Rudnaya Gora at Noril'sk in the south, for which an original grade of 1,47 per cent copper and 1,05 per cent nickel was reported. Production from that area started in 1935, and by 1940 had grown to account for 35 per cent of PGM production in the then USSR, and 90 per cent by 1977. Considering what has been said about the other producer areas above, it probably now exceeds 95 per cent, and may even make up 100 per cent of the total current production of the CIS. The official controlling authority of the mines in that area is currently Noril'sk Nikel.

The Noril'sk ore junction on the Yensey River hosts the Noril'sk I and II (the latter subeconomic) and the Mount Chernaya deposits, but all the older mines on these orebodies are probably exhausted. According to Naldrett (1992), only one underground mine (probably the Zapolyani mine) and one open pit (probably the Medvezhy Ruchi or Bear Creek opencast mine) are still operational. Their grades are reportedly between 0,75 and 1 per cent copper, 0,5 per cent nickel and up to 11 g/t PGM (Lines, 1979).

The bulk of production now comes from the Talnakh area, some 18 km north of Noril'sk, discovered in 1965. The Talnakh ore junction consists of two main orebodies, the smaller Talnakh orebody east of the Noril'sk-Kharealakh fault (hereafter referred to simply as the fault) and the huge Oktyabr'sk (October) orebody to the west of it. The orebodies become progressively deeper northwards, so that the depth of the mines ranges from 300 to 2000 m below surface. At the south end of the Talnakh area, the shallow Mayak (Poppy) mine, which started producing in late 1965, exploits both the Talnakh and Oktyabr'sk orebodies on both sides of the fault. This also applies to its northerly neighbour, the Komsomolsky mine, which commenced production in 1971. The Mayak and Komsomolsky mines originally produced massive ore (the latter also the copper-rich variety), but this has probably been exhausted so that both produce only disseminated ores (Professor Morris Viljoen, personal communication, 1993). The main production now comes from the very large Oktyabr'sk I and II mines (production started in 1974) and the Taimyr mine (which came into production after 1978), which are particularly rich in massive ores. Replacements for these mines are the deeper northerly Glubokij mine on the Oktyabr'sk orebody west of the fault, and the deeper Skalisty (Rocky) and Severnij (Northern) mines. The latter two mines are situated on the thin elongate Talnakh orebody (in plan), east of, and parallel to, the fault. Estimates of the production capacity of all these mines vary; the ISMI paper suggests 17,8 Mt/y at a PGM grade of 3,8 g/t (i.e. 67 640 kg or 2 174 673 oz per year), but Johnson Matthey estimate 14 Mt per year of ore grading from 5 to 15 g/t PGM per year (70 000 to 210 000 kg or 2 250 550 to 6 751 647 oz per year). The output of the Oktyabr'sk mines alone is thought to be 5 Mt/y. It is interesting that Johnson Matthey predicts that the grade is due to decrease in the next few years, due to the greater proportion of disseminated ore that is mined as operations move to the deeper mines compared to the large mix of massive ore which was mined in the past. The average recovery grade for the Noril'sk-Talnakh deposits is 7,85 g/t (Table 2.11), which, if the tonnage of Johnson Matthey is used, amounts to about 110 000 kg or some 3 537 000 oz of PGM per year. Average figures for the 1985 to 1989 period, however, suggest that the yearly production is 123 556 kg or 3 972 412 oz (Pt:Pd = 1:2,92) with a growth rate of 2,58% per year.

The estimates of the Russian historical production information in Table 3.3 are based on a number of sources as before, but are guided principally by the USBM estimates. The table is largely self-explanatory, although comment is reserved until a later portion of this report.

The evergreen Russian PGM tonnage reserve estimate of Buchanan (1979), which is so frequently quoted in world reviews, is clearly a gross understatement of the true situation. The *in situ* resources quoted for Russia elsewhere in this review (17 875 200 kg), are 2,87 times those of Buchanan (6 220 696 kg), and this estimate is low because it ignores the new orebody near the top of the Noril'sk-Talnakh sills, which is said to contain some 40 g/t PGM.

The smelting of the ores is undertaken at the mines, the last (Nadezhda) smelter of the three in operation having been erected at the Okyabr'sk mines in 1980. Officially these smelters pump 2,4 Mt of sulphur dioxide per year into the atmosphere, despite objections from the Russian populace and the neighbouring Scandinavia states. *Izvestia* recently reported that Noril'sk Nikel had been fined $3,0 million for polluting large areas (35 135 ha) of Siberian forest, but this was later reduced to $2,0 million by arbitration. It is thus paying the price for the policies pursued by the former Soviet government, in which environmental standards were sacrificed for ever greater production and indiscriminate industrial development. In February 1992, it was announced that one of the smelters was being closed for maintenance, estimated to last for six months. In the same month, Noril'sk Nikel signed a technical-assistance protocol with Inco of Canada.

Noril'sk Nikel markets its nickel and other base-metals direct to any domestic or foreign customer, the output being shipped via the Yensey river to the Arctic