is also a nickel refinery at Clydath in Wales (UK) and a copper refinery at Sudbury, but it is not clear at which of the refineries the PGM are actually processed. From 1988 to 1990, Inco's average annual production of Pt + Pd + Rh was 9250 kg or 297 394 oz (Pt:Pd:Rh = 1:1,31:0,12), but declining at a rate of 2,57 per cent per annum. Inco was said to have increased production in 1991 following a switch from the North to the South Thompson Open Pit and the Lower Coleman mine at Sudbury, because of arsenical contamination and low PGM output. South Thompson and Lower Coleman have higher PGM grades. In July and August 1992, the Inco mines closed down due to low nickel prices, but this is not expected to adversely affect the PGM output.

Inco has discovered high PGM concentration (Section 2.6.1 and Table 2.22) at its Victor deposits on the north-eastern rim of the Sudbury basin, and also in the Levack area near the McCreedy East mine (average 7,9 g/t PGM + Au + Ag), which is due to open in 1993. It is Inco's stated intention to close many of its lower-grade operations and replace them with higher-grade mines. However, since the PGM do not always correlate with high nickel values, this may have only a marginal effect on the PGM output, and the deep, higher-grade PGM prospects could probably only come on stream in five to ten years' time.

Falconbridge Nickel Mines Ltd. Since September 1989, this company has been jointly and equally owned by Noranda of Canada and Trelleborg of Sweden. Falconbridge produces lesser amounts of PGM than Inco from the following mines in the Sudbury district: Falconbridge, Lindsley, Lockerby, Omex, and Strathcona. Falconbridge East, Fecunis, Longreach South and North, and Manibridge near Waboden in Manitoba, are now closed. The company has two concentrators, at Falconbridge and Strathcona, and a third on stand-by at Fecunis Lake. It operates a nickel smelter at Falconbridge and a nickel/PGM refinery at Kristiansand in Norway, to which the nickel–copper matte from Canada is sent for refining. Part of the platiniferous sludge produced in Norway was previously sent for PGM refining to Engelhard Minerals and Chemicals, but much is now done in Norway. The Kristiansand plant also recovers PGM from nickel–copper matte from Selibe-Pikwe in Botswana and from Noril'sk Nikel in Russia. In the period 1988 to 1990, Falconbridge produced an average of 3142 kg or 100 439 oz of Pt + Pd + Rh (Pt:Pd:Rh ratio 1:2,28:0,17), with an annual growth rate of 38,72 per cent per annum. In November 1991, Falconbridge announced its intention of closing its Sudbury operations during the summer of 1992 and, should this materialize, its PGM output for the year would be reduced by about 10 per cent. Deliveries of PGM from Falconbridge increased in 1992, but production was scheduled to decline in 1993.

Lac Des Isles. For many years Boston Bay Mines held this deposit, located some 80 km north of Thunder Bay in north-west Ontario. It was then taken over by Madeleine Mines, who were lately joined by The Platinum Group Mines. In October 1991, Madeleine Mines was taken over by Kaiser-Francis Oil of Oklahoma, who now manage the deposit. Trial opencast mining and milling was undertaken on the Roby zone (6,4 g/t PGM, Pt:Pd ratio 1:7) between November 1990 and September 1991, but the Ontario Ministry of the Environment stopped operations in October 1991 until the mine complied with their legislation. Minor changes were required to the 90 000 t/month plant. Operations did not resume in 1992, since the mine failed to comply with Ontario's strict environmental regulations. Mill output was to be toll-smelted and toll-refined, with the expected production being 622 kg or 20 000 oz platinum and 4354 kg or 140 000 oz palladium per year, hopefully in 1993/1994.

Platinum prospecting has been subdued in Canada over the past few years. Literally hundreds of small Archaean greenstone nickel deposits exist in Canada, but these would be hard-pressed to consider production at the present cost of infrastructure, mining, and beneficiation. Past PGM producers include the Langmuir mine (Norada 51 per cent, Inco 49 per cent) in the Timmins area, the Kanichee mine near Temagami, Dumbarton Mines' (Canadian Faraday & Maskwa Nickel–Chrome Mines) mine near Bird River in Manitoba, and the Thierry (Union Miniere) mine near Pickle lake. A further potential producer is the Great Lakes deposit in north-west Ontario, owned by Bolidon Aktiebolag of Sweden (reserves of 45,6 Mt grading 0,344 per cent copper, 0,183 per cent nickel, 0,196 g/t platinum, 0,788 g/t palladium, 0,011 g/t ruthenium, 0,021 g/t rhodium, 0,001 g/t iridium, and 0,004 g/t osmium: Vermaak 1985a).

3.3.2. *Canadian Production*

Some interesting calculations from historical data from the Sudbury area were undertaken by Vermaak (1985a). From 1920 to 1979, the average annual platinum production was 3207 kg or 103 104 oz (growth 9,67 per cent per year), and palladium 3309 kg or 106 387 oz (growth 9,49 per cent per year). From 1961 to 1975, the average tonnage milled was 19 463 240 t/y, which yielded the following production.

		Value distribution (US$), %
Ni	170 551 t	72,86
Cu	161 174 t	20,82
Co	1 601 t	0,95
PGM	12 817 kg	4,43
Au	1 758 kg	0,39
Ag	55 071 kg	0,43
Se	925 271 kg	0,11
Te	64 202 kg	0,01

Details of the total Canadian PGM production from 1930 to 1992 are provided in Table 3.4. The details up to 1959 are derived from official Canadian publications (Vermaak, 1985a), but thereafter the sources are diverse, guided mostly by the USBM dta.

Table 3.4

Estimates of Canada's historical production of the PGM, 1950–1992 (kg)

Period		Individual annual data for the five-year period						Annual growth/ decline, %
		1	2	3	4	5	Mean	
1930–34	Pt	1 058	1 393	850	770	3 614	1 573	+20,49
	Other PGM	1 058	1 459	1 170	964	2 611	1 452	+14,94
	Total PGM	**2 116**	**2 852**	**2 020**	**1 734**	**6 225**	**2 989**	**+18,06**
1935–39	Pt	3 277	4 092	4 335	5 018	4 631	4 271	+ 9,37
	Pd	2 637	3 224	3 727	4 071	4 211	3 574	+12,41
	PGM	**5 914**	**7 316**	**8 062**	**9 089**	**8 842**	**7 845**	**+10,75**
1940–44	Pt	3 374	3 867	8 872	6 834	4 900	5 569	+14,06
	Pd	2 847	3 030	6 923	3 919	1 335	3 611	–11,82
	PGM	**6 221**	**6 897**	**15 795**	**10 753**	**6 235**	**9 180**	**+ 4,59**
1945–49	Pt	6 477	3 788	2 941	3 769	4 780	4 351	– 5,94
	Pd	14 266	3 657	3 432	4 614	5 668	6 327	–14,90
	PGM	**20 743**	**7 445**	**6 393**	**8 383**	**10 448**	**10 678**	**–11,78**
1950–54	Pt	3 871	4 773	3 804	4 278	4 801	4 305	+ 3,26
	Pd	4 626	5 129	4 896	5 164	5 889	5 141	+ 5,02
	PGM	**8 497**	**9 902**	**8 700**	**9 442**	**10 690**	**9 446**	**+ 4,20**
1955–59	Pt	5 303	4 708	6 207	4 544	4 650	5 082	– 2,94
	Pd	6 664	5 084	6 736	4 801	5 293	5 716	– 5,05
	PGM	**11 967**	**9 792**	**12 994**	**9 345**	**10 205**	**10 861**	**– 3,59**
1960–64	**PGM**	**15 041**	**13 010**	**14 843**	**11 124**	**11 702**	**13 104**	**– 6,37**
1965–69	Pt	6 065	5 194	5 526	6 345	4 043	5 381	– 5,93
	PGM	**14 405**	**12 315**	**12 487**	**15 058**	**9 594**	**12 776**	**– 5,92**
1970–74	Pt	6 314	6 127	5 000	4 400	4 700	5 308	– 8,80
	PGM	**15 005**	**14 779**	**12 630**	**11 018**	**11 963**	**13 079**	**– 7,20**
1975–79	Pt	4 900	5 477	5 712	4 628	4 199	4 983	– 4,66
	PGM	**12 417**	**13 082**	**14 475**	**9 376**	**8 456**	**11 541**	**–10,43**
1980–84	Pt	4 830	4 610	2 788	2 668	4 251	3 829	– 7,71
	Pd	6 243	5 674	3 717	3 669	5 384	4 937	– 7,06
	Ru	472	507	200	208	368	351	–12,97
	Rh	573	600	202	210	454	408	–14,06
	Ir	234	252	97	103	187	176	–12,94
	Os	239	259	100	107	187	178	–12,84
1980–84	**PGM**	**12 596**	**11 902**	**7 104**	**6 965**	**10 831**	**9 879**	**– 8,04**
1985–89	Pt	4 146	5 242	4 354	5 393	4 244	4 676	+ 0,75
	Pd	5 252	5 486	5 910	5 643	4 442	5 347	– 3,02
	Ru	366	512	211	462	636	437	+10,54
	Rh	365	465	250	562	718	472	+16,68
	Ir	174	239	95	231	315	211	+12,22
	Os	182	251	110	250	340	227	+13,27
1985–89	**PGM**	**10 485**	**12 195**	**10 930**	**12 541**	**10 695**	**11 370**	**+ 0,68**
1990–92	Pt	4 829	4 384	4 381	–	–	4 531	– 4,75
	Pd	5 044	6 028	6 019	–	–	5 697	+ 9,24
	Ru	423	173	164	–	–	253	–37,73
	Rh	478	196	191	–	–	288	–36,79
	Ir	209	86	82	–	–	126	–37,36
	Os	226	93	89	–	–	136	–37,25
1990–92	**PGM**	**11 209**	**10 960**	**10 926**	**–**	**–**	**11 031**	**– 1,27**