gold, and copper values increasing progressively from the hangingwall ores, through the main ore zone into the deep ore zone. Ruthenium, rhodium, iridium, and osmium showed a reverse trend, so that these elements are virtually absent in what have been referred to as the copper and deep-copper zones.

No aspect of the controversy surrounding the genesis of the Sudbury Irruptive or its ores and their complex mineralogy will be considered in this report. The vast volume of analytical data on production and plant products has been thoroughly evaluated (Vermaak, 1985a). The data suggest an average millhead grade is

Ni 1,139 per cent
Cu 1,088 per cent
Co 107,7 g/t
PGE 0,856 g/t
Au 0,177 g/t
Ag 3,687 g/t
Se 3,614 g/t
Te 0,285 g/t.

The PGE grade represents an 80 per cent recovery from the *in-situ* ores. The *in-situ* value of the ore is therefore 1,07 g/t PGE, which is higher than the tenor of 0,777 g/t suggested by Allen (1961) but lower than the 2,351 g/t noted by O'Niell and Gunning (1934). In the present work, 17 full analyses of the individual PGE were used to calculate the following average distribution: 43,25 per cent platinum, 44,52 per cent palladium, 4,08 per cent ruthenium, 5,36 per cent rhodium, 1,89 per cent iridium, and 0,90 per cent osmium. The resources of the PGE will be considered later.

2.6.2. *The Lac des Isles Deposits*

This deposit occurs some 80 km northwest of the Great Lakes port of Thunder Bay in western Ontario. Discovered in 1963, the deposit was held at different times by a variety of companies, who delineated the ore in the 'C' discovery zone, and eventually the Roby zone, which currently constitutes the main area of interest.

The Lac des Isles occurrence is part of a swarm of ultramafic bodies that extends some 320 km northward along the Wabigoon belt from the Minnesota-Canadian border into Ontario. These bodies are typical of Archaean ultramafic layered or zoned complexes that intrude greenstone belts world-wide. The isoclinally folded Archaean metavolcanics and metadiabases strike NE to ENE and dip steeply SE, constituting part of the northern limb of the Eayrs Lake-Stearnes Lake syncline, which has been intruded by diabase sills and dykes related to the late-Proterozoic Keeweenawan period and planed by glaciers at a later stage.

According to Vermaak (1985a), the Lac des Isles complex is a vertically zoned igneous plug, reminiscent of those in the Ural mountains in Russia. The semi-circular northern ultramafic portion was the last to be intruded, and consists of a central core (20 per cent of the area) of peridotite, with minor websterites and gabbros, surrounded by pyroxenites (50 per cent of the area), and a discontinuous rim of harzburgites and wehrlites (30 per cent of the area). All the rocks are serpentinized and uralitized. The southerly McKernan Lake phase consists of an older, altered western intrusion of steep easterly dipping interlayered pyroxenites (10 per cent), norites (20 per cent), and gabbros (80 per cent), and a fractionated sequence of norites, gabbros, and anorthosites, younging eastwards, where it has been transgressed by the later intrusion of the eastern gabbro. Sulphides make up to 3 per cent by volume of the mineral- and size-graded western gabbro, which contains the mineralized Roby zone. The eastern gabbro contains magnetite–ilmenite–spinel-rich norites and gabbros, and is characteristically poor in sulphides, but its emplacement caused shearing and mobilization of the base and precious metals into shear zones.

According to Dunning (1979), the PGE are concentrated in the orthopyroxene-rich and other melanorites of the western intrusion. The economic zone has a thickness of 70,5 m, and primary nickel in the 100 to 600 ppm range, in areas with more favourable primary PGE values. However, it has been demonstrated that the sheared and altered spinel-bearing pyroxenites of the Roby zone contain the highest PGE values yet recorded, probably indicating mobilization of the PGE into altered rocks containing secondary metamorphic sulphides. Dunning *et al.* (1980) showed that the best correlation between base-metal and PGE is in the norites and anorthosites; the correlation is poor in the gabbros and websterites.

The ore is concentrated in the 'C' discovery zone (400 m by 100 m) and in the richer Roby zone (1220 m by 50 m) situated 520 m north of the 'C' zone. Both areas have been thoroughly trenched and drilled by the various companies. The results were evaluated by Vermaak (1985a). The Roby zone has a 9 m high-grade footwall band with an open-ended 300 m strike (at last reporting) assaying 10,57 g/t PGE. The latest prospecting gave the following overall grades: 0,214 per cent nickel, 0,205 per cent copper, 5,21 g/t PGE (Pt:Pd ratio 1:9,39). However, ore tonnages of 20 Mt and grades of 6,4 g/t PGE are reported characteristic of the Roby zone, and are accepted as such.

2.6.3. *Assessment*

Sutphin and Page (1986) in the ISMI report provided data on the Sudbury reserves for 1983: Inco has 360 Mt grading from 0,7 to 1,0 g/t PGE (which includes the reserves for the Thompson and Shebandowan mines), and Falconbridge has 66,769 Mt grading 0,45 g/t PGE. These are assumed to be millhead grades. In Table 2.22, the PGE reserves at Sudbury have been reduced by my calculated amount extracted by the Sudbury mines from 1983 to 1992 (55 522 kg of PGE). Recent press reports suggest that two major ore discoveries have been made at Sudbury; a deposit of between 18 and 36 Mt grading 12,2 g/t PGE + Au, and another deposit of 7 Mt grading 10,9 g/t PGE + Au. I have assumed that tonnage to total 40 Mt grading 10 g/t PGE (*in situ*, without gold) in Table 2.22. Since Lac de Isles is an opencast operation, a mining loss of 40 per cent has been assumed, to yield the millhead reserves indicated. The

Table 2.22
In-situ and millhead reserves and provisional resources of Canada, t

Deposit	Pt	Pd	Ru	Rh	Ir	Os
In-situ:						
Sudbury	158,7	163,4	15,0	19,7	6,9	3,3
Sudbury addition	171,6	176,7	16,2	21,3	7,5	3,6
Lac des Isles	12,8	102,2	–	–	–	–
Total	**343,1**	**442,3**	**31,2**	**41,0**	**14,4**	**6,9**
Thousand troy oz	11 030,9	14 220,3	1 003,1	1 318,2	463,0	221,8
Millhead:						
Sudbury	121,3	124,9	11,4	15,0	5,3	2,5
Sudbury addition	138,4	142,5	13,1	17,2	6,0	2,9
Lac des Isles	8,5	67,9	–	–	–	–
Total	**268,2**	**335,3**	**24,5**	**32,2**	**11,3**	**5,4**
Thousand troy oz	8 622,8	10 780,1	787,7	1 035,3	363,3	173,6
Provisional resources:						
Kapkichi, Ont.	60,2	330,4	–	–	–	–
Thompson belt	34,9	92,3	51,8	10,2	13,2	19,3
Thierry, Ont.	17,8	98,6	–	–	–	–
Ungava Peninsula	19,5	46,0	8,2	3,7	1,4	1,7
Clearwater, N.B.	3,0	7,6	0,8	0,6	0,2	0,2
Nameiban, Sask.	1,7	4,7	2,7	0,5	0,7	1,3
Carmen Bay, Ont.	1,3	3,7	1,0	0,4	0,4	0,5
Copper Mount, B.C.	1,1	2,9	0,5	0,2	0,1	0,1

list of provisional resources reflect the eight largest deposits containing PGE in Canada (Vermaak, 1985a).

The Abitibi belt, Alexo, Birch Tree, Bird River, Bucko, Canalask-White River, Donaldson W, Dundonald, Dumbarton, Dumont, Farley, Great Lakes, Kanichee, Katniq, Key Lake, Langmuir, Lynn Lake, Manbridge, Maskwa, Mc Watters, Moak Lake, Montcalm, Muskox, Mystery Lake, North Rankin, Pipe, Redstone, Sothman, Star Lake, Texmont, Thompson, Twin Lake, Tulameen, Vermillion, Waboden, and Wellgreen deposits have been assessed before (Vermaak 1985a). Small amounts of PGE are produced by the partnership of the Hudson Bay Mining and Smelting Co. and Outokumpu Oy of Finland from the Namew Lake deposit.

Prospecting and feasibility studies were recently being undertaken by Auralba Mining (Canada) Ltd at the Marathon and Crystal Lake copper properties (42,5 Mt containing 1,78 g/t PGE; held by Flack Resources Ltd). A deposit at Trout Lake (<9 g/t PGE) was also investigated by a consortium of the International Platinum Corp., Degussa AG of Germany, and Jenkim Holdings (Canada) Ltd, while La Fosse Platinum Group were examining the Labrador trough in Quebec. Longreach Resources Ltd were prospecting for PGE near Termiskaming in the Yukon, while All-North Resources and Chevron were investigating the Wellgreen deposit. In the Northern Territories, International Platinum Inc. and Equinox Resources were examining the Muskox intrusion, and Asamara Minerals the Rankin Inlet deposit. Needless to say, many of these projects have been abandoned with the recent fall in PGE prices.

Reports of an exciting new layered complex, which was apparently eroded to give rise to the Goodnews Bay placers, recently appeared in the press. Regrettably, no further data is available. The Salt Chuck, Snettisham, Union Bay, and Yakobi island (Bohemia basin) zoned magmatic deposits are not considered in this report. The placer deposits will be examined separately.

Figure 2,20 compares the distribution of the PGM in the deposits of Zimbabwe, the USA, and Canada.

2.7. People's Republic of China

The Jinchuang deposit in the People's Republic of China has been described by Shibo and Buchanan (1989) and Chai and Naldrett (1992). This is a major nickel–copper deposit hosted by a 1509 My series of ultramafic intrusions emplaced into Archaean gneisses, marbles, and migmatites in the southwest margin of the Sino-Korean platform of northwest China. These near-vertical bodies, 6 500 m long by 300 m wide, were intruded along northwest-elongated faults, and are the preserved cumulate roots of a series of major ultramafic intrusions. Three major orebodies, nos 24, 1, and 2, separated by faulting, constitute the major ore source, but smaller orebodies are known to occur. Their host rocks are considered to be three separate magma subchambers of the major 'mother' intrusion. The faulted western subchamber, hosting the no. 24 orebody, outcrops at surface (2100 m long, 275 m wide), and con-