

which treats palladium-rich greenstone ores from the Kambalda and Windarra mines and matte from the Kalgoorlie smelter. The PGM recovery is low, 2.18 g per ton of refined nickel, compared with Canada's 56 g/t. However, some of the Australian material also reaches the refining facilities in Japan, and these PGM are likely to be reported there. For the period 1985 to 1990, Australian output of Pt + Pd, apparently entirely from the refining source, averaged 514 kg or 16 525 oz per year (Pt: Pd ratio 1:4.44) at a declining rate of 2.16 per cent per year.

Hunter Resources Ltd has explored the Munni-Munni prospect in Western Australia where between 20 and 30 Mt of reserves at an average grade of 2.9 g/t Pt + Pd + Au (Pt: Pd ratio 1:1.18) was established (Barnes *et al.*, 1990). Pancontinental Mining of Australia and Degussa AG of Germany teamed up to prospect the Windimurra complex (up to 1.7 g/t PGM, Perring and Vogt, 1989) and the Panton Sill prospect (2.2 Mt at 6.2 g/t PGM + Au, Johnson Matthey, 1991). Under pressure from the aborigines (who regard the area as sacred) and backed by environmentalists, the Australian government has blocked exploration for gold and small amounts of PGM at Coronation Hill in the Kakadu National Park, Northern Territories. Austmin Gold and Dragon Mining have announced a grade of 2.35 g/t Pt + Pd from drilling of the shallow Range Well complex near Meekatharra in Western Australia. At present PGM prices, none of these projects appears viable.

3.5.2. Colombia

Colombia produces PGM only from placers, the main producer being Cia Minera Choco Pacifico, the dredging subsidiary of Compania Mineros Colombianos, which is said to produce between 35 and 40 per cent of the officially reported Colombian output. However, it is estimated that unofficial PGM production, which is sent to jewellers in Mexico, at least equals the official production, which goes to the USA for refining. From 1985 to 1989, the production of platinum increased from 362 kg (12 000 oz) to 973 kg (31 000 oz), an average escalation of 29.33 per cent per year. Average production for that period was 654 kg or 21 027 oz.

3.5.3. Ethiopia

Average production for the period 1985 to 1990 was a mere 1.8 kg (58 oz), but it is doubtful whether exploitation will continue under the present unrest, even with a US presence.

3.5.4. Finland

Finland produces PGM from the copper-nickel mines (Hammaslahti, Hitura, Kotalahti, Pyhasalmi, Stromie, Virtasalmi and Vuonos) operated by the state-owned company Outokumpu Oy. A nickel refinery and a copper smelter at Harjavalta, and a copper refinery at Pori, probably produce the PGM sludge, but it is unclear where the refining of the PGM is undertaken, possibly outside of Finland. From 1985 to 1989, Finland produced 175 kg or 5626 oz of Pt + Pd (Pt: Pd ratio 1:1.33) at a

growth rate of 6.28 per cent per year. The Keivitsa layered complex (3 km in diameter), some 40 km north of the town of Sodankyla in Finnish Lapland, is a new Finnish discovery reported in the Mining Journal (7/1993). The orebody reputedly contains between 50 and 100 Mt with PGM + Ni + Cu at an equivalent copper grade of between 1.5 and 2 per cent, but considerably more exploration is required. If payable, mining could commence between 1995 and 1997. Finland's PGM resources are expanding (Section 2.3), and the outlook for increased PGM production is certainly excellent.

3.5.5. Japan

Japan recovers PGM as a by-product of its nickel-copper refining industry, which is based on foreign nickel-bearing ores. These are mainly lateritic ores from New Caledonia, and sulphide ores from Acoje Mining in the Philippines, which are rich in PGM (420 g/t of refined nickel, compared with 1.8 g/t in Canada). Matte from Australia and copper-bearing ores from Canada, Chile, Namibia, Peru, and the Philippines are also processed. The chief nickel refiners are Sumitomo Metals and Mining Co (66.7 per cent of output), Shimura Kakao (29.6 per cent), and Nippon Mining (3.7 per cent). Large amounts of PGM products are manufactured by Sumitoto Shoji Kaisha Ltd and by Ishifuku Metal Industry Co. From 1985 to 1989, the average Japanese PGM output amounted to 2001 kg or 64 335 oz (Pt: Pd ratio 1:1.8), but production declined by 3.49 per cent over that period.

3.5.6. Yugoslavia

Yugoslavia has produced PGM since 1976, when the state mining company, Bor, announced its intention to do so. All the production is probably derived from the Krivaljia copper mine, where the ores contain significant quantities of precious metals. From 1985 to 1989, the average output was 149 kg or 4790 oz of PGM (Pt: Pd ratio 1:6.45) increasing by 24.19 per cent per year. However, with the fragmentation of the former Yugoslavian state and the war that has erupted as a consequence, PGM production may have been completely curtailed.

3.5.7. Zimbabwe

The PGM were initially discovered in the Great Dyke in 1914, and prospecting by the Grainger brothers in the Wedza area (1926-1929) established an average head grade of 4.3 g/t from surface trenching. Since that time, prospecting has been confined mainly to the Wedza area in the south and the Hartley-Selous area in the north.

Union Carbide first prospected the Wedza area in two stages: the Wedza mine (1969 to 1972) and the Mimosa mine (1974 to 1978), where mineable reserves of 78 Mt and geological reserves of 120 Mt were established. A planned mine would have produced 4106 kg of platinum, 3172 kg of palladium, 4700 t of nickel and 3600 t of copper per year, and employed 1800 people. The Anglo American Corporation, in conjunction with

Union Carbide, carried out extensive exploration in the Wedza-Unki area in the 1960s and 1970s.

Union Carbide was also the first to explore the Hartley-Selous area (1968 to 1972) where 186 boreholes were drilled and 6000 t of ore was produced. However, mining ceased due to support problems. The area was then acquired under exclusive prospecting order (EPO), and subsequently dubbed the Hartley Platinum Project in the mid-1980s by the Delta Gold company. The area was evaluated extensively, with a further 23 boreholes totalling a combined depth of 4205 m drilled from October 1988 to June 1990. On 23 October 1990, Delta Gold signed an agreement with BHP Minerals (33 per cent and 67 per cent respectively), and 80 more boreholes totalling 28 600 m were drilled as part of a feasibility study. The mine envisaged has ore reserves of 136.9 Mt (no depth provided), will produce 2 Mt of ore per year, and employ 2700 people. The annual output from a 1.2 m stoping width will be 4354 kg platinum, 3110 kg palladium, 342 kg rhodium, 653 kg gold, 2900 t nickel and 2100 t copper. An announcement of whether mining would be feasible was expected at the end of 1993. However, if the mine is to be viable, production can only be expected to begin in 1996.

Much prospecting has been carried out in other areas as well. The Selous Project on the western limb of the Hartley complex was prospected and drilled from 1992 to May, 1993 (24 boreholes totalling 14 953 m). To the south, the Mhondora Joint Venture (Delta Gold purchased Plateau Mining's share of 24 per cent, AAC's Valley Exploration 38 per cent, and Rio Tinto RTZ 38 per cent) undertook drilling in the area from August 1992 to July 1993. The Joint Venture partnership with Plateau Mining also previously investigated the Chegutu claims covering an area of 210 km². A feasibility study suggests a mine production of 0.5 Mt/year yielding 622 kg platinum, 591 kg palladium, and 62 kg rhodium per year. Union Carbide has been reassessing the old Wedza-Mimosa project, which was last investigated in 1975, and Cluff Resources examined the far northern Musungesi mafic complex in 1990, where large low-grade reserves were established.

From 1985 to 1989, Zimbabwe produced a very modest 60 kg or 1929 oz per year on average (Pt: Pd ratio 1:1.57), increasing by 8.71 per cent per year.

3.5.8. Other Producers

Other producers have included the former German Democratic Republic, which produced a rather staggering mean output of 2049 kg platinum and 362 kg palladium until an abrupt stop in 1987. The source of the ore is unknown, but the sudden end to production may indicate either a cessation of domestic mining after the collapse of the Berlin wall, or that the PGM were being refined for a foreign country. Greenland has also been receiving attention, notably the very small Skaergaard intrusion (Canadian Platinova and Pegasus Gold). Rio Tinto Zinc (RTZ) have a 51 per cent stake in the platinum-gold prospecting at Kap Edvard Holm

in Greenland but, according to all reports, results have been disappointing.

3.6. World PGM Production

World production of platinum, palladium and the platinum-group metals by country from 1981 to 1992 is shown in Tables 3.7, 3.8, and 3.9. The annual percentage growth or decline tendencies are particularly enlightening.

In assessing the production figures for these metals, several factors should be born in mind. Firstly, the degree of confidence that can be ascribed to the figures varies considerably, and the data for South Africa, Canada, and the USA are considered much more reliable than those for Russia (CIS) and certain other countries. This is particularly important in the case of an important supplier like Russia, where the estimated production data may incorporate substantial errors. A second factor is the separation of actual mine production from non-toll or in-house secondary metals derived from the treatment of scrap or discard materials. The latter comprise an important component of supply, the estimation of whose magnitude is subject to large errors, as there are no hard-and-fast rules for reporting amounts to central authorities in many countries that produce such secondary PGM. It is, moreover, virtually impossible to determine the amount of such precious metals, used by the diverse chemical industries or as electrodes or electrode coatings, which are recycled. Data on secondary metal production are supplied only for the USA, as they are not freely available from other important countries such as Japan and Europe. The production of secondary recycled metals may assume major importance in future, as increasing amounts of PGM are recovered worldwide from spent automobile catalysts. Finally, a third uncertainty factor is that major unknown stocks of the PGM are held by producers, refiners, large industrial users, and investment interests throughout the world to meet future demands.

Although prognoses for the future of the PGM will not be discussed in this Section, it is prudent to mention two major factors that may affect future supplies. Firstly, the planned production expansion by existing South African mines, as well as the introduction of a further major supplier (Northam), is perceived in some quarters as having the potential to oversupply the world's PGM markets by the mid-1990s. Moreover, Russia is unlikely to deviate from past patterns of supplying platinum metals to world markets only in accordance with its own priorities, so that the source of that supply cannot ever be guaranteed when required. On the other hand, financial needs can cause Russia to oversupply world markets, as in the recent past, causing severe price disruptions.

There are, unfortunately, also some doubts regarding the security of future PGM supplies. It would be naive to ignore the existence of political unrest in much of the African continent, specifically in the Republic of