

# PLATINUM–GROUP METALS

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In 2000, the average price of palladium, platinum, rhodium, and ruthenium increased by 90%, 45%, 120%, and 219%, respectively. The price increases for platinum and rhodium can be attributed to increased demand, mainly from the automobile sector. Palladium prices, for the third consecutive year, were influenced by unreliable imports from Russia. Russia accounted for 51% of U.S. palladium supply and 3% of U.S. platinum supply in 2000. Prices for the relatively unknown ruthenium increased sharply to an average \$129.76 per troy ounce in 2000 from \$40.70 per ounce in 1999. Ruthenium prices were driven by increased demand from the electronics sector and reports of the development of new ruthenium-based superalloys for use in aerospace applications.

Higher prices were followed by an increase in the pace of exploration for PGM, and a growing number of joint ventures were signed in recognition of the strong fundamentals for these metals. Decreases in the price of PGM in the first part of 2000 did little to dampen enthusiasm for further exploration because of expected increases in demand from the automobile industry, jewelry manufacturing, and other industrial applications as well as limited supplies of the metals from Russia.

The automobile industry continued to be the major consumer of PGM. In 2000, autocatalysts accounted for approximately

98% of rhodium demand, 66% of palladium demand, and 41% of platinum demand. Despite the overall increase in vehicle sales in 2000, demand for palladium by auto manufacturers declined, as automakers and electronic component makers made concerted efforts to reduce the palladium content of their products. U.S. demand for platinum in jewelry manufacture, on the other hand, continued to grow and has become one of platinum's largest applications. Demand for platinum in the automobile industry increased in Europe due to higher loadings on catalysts in diesel automobiles. Diesels have been gaining substantial market share in Europe over the last several years. In the United States, a return to the use of more platinum in autocatalysts for cars powered by gasoline began in late 1999 and gained momentum in 2000. This trend was expected to continue, especially if the price of palladium remained above that of platinum. Demand for platinum metal in the industrial sector continued to increase; demand was expected to be up by more than 3,000 kilograms (kg). Increased platinum use in computer hard disks caused demand in electrical-electronics applications to increase substantially.

Growth in consumer demand for iridium by the glass industry for crucibles was more than offset by lower demand for use in autocatalysts.

## Platinum-Group Metals in the 20th Century

At the beginning of the 20th century, the use of PGM in the United States was limited to the manufacture of laboratory ware, as a catalyst in the production of sulfuric and nitric acids, and in jewelry. Almost all U.S. production of PGM at that time was from placer deposits in the Goodnews Bay district of southwestern Alaska and gold placers in California. In Canada, platinum was produced as a byproduct of nickel copper-copper mining. In 1920, a large primary platinum deposit was discovered by Hans Merensky in a platiniferous reef in South Africa in the Bushveld Igneous Complex.

After an active period of placer mining and prospecting for precious metals, exploration for PGM in the United States essentially ceased in the early 1900s because of the availability of foreign supplies and the lack of directly applicable modern geologic, geothermal, and geophysical techniques for finding new deposits. U.S. production was less than 800 kilograms per year while consumption was estimated at about 9,000 kilograms. In the mid 1960s, analytical techniques for determining PGM in geologic materials at the low parts-per-billion level were developed. With a better understanding of the geochemistry and geology of the elements, modern programs of exploration began to find previously unknown occurrences of PGM. The most promising occurrences were found in Stillwater, Sweet Grass,

and Park Counties in southern Montana. In the early 1970s, geologists discovered palladium and platinum along the J-M Reef in Stillwater County. In 1979, a partnership was formed to develop PGM discovered in the area. In 1986, underground mining operations began at the Stillwater property.

By 2000, the fundamental structure of the markets for palladium, platinum, and the other PGM changed substantially. World production had increased to about 365,000 kilograms. South Africa, Russia, and Canada remained the world's major producers while the United States became a minor source, producing about 13,400 kilograms in 2000. PGM-based catalytic converters, developed in the mid-1950s, had become required equipment on all automobiles manufactured in the United States. Autocatalysts were, by a significant margin, the largest end-use of PGM in the country, accounting for about 48,000 kilograms or 40% of consumption in 2000. Electrical and electronics, a major end-use in 2000, accounted for about 32,000 kilograms or 27% of overall PGM consumption. Jewelry, a major end use of platinum worldwide (especially in Japan), accounted for only about 8,000 kilograms (7%) of U.S. consumption in 2000. Another 44,000 kilograms (37%) of PGM were used in other domestic applications, including petroleum reforming catalysts, chemical process catalysts, dental and medical devices, and the glass industry.

Ruthenium pastes are used in the manufacture of resistors, which are found in all electronic devices. In 2000, sales of products such as mobile phones, computers, and video games pushed the output of resistors up by more than 30%. Also, prices were influenced by reports of a ruthenium-based material that will eventually permit hard disk drives to store 100 gigabits of data per square inch of disk area. Current technology is limited to data densities of 20 to 40 gigabits per square inch.

According to Johnson Matthey plc, global automobile demand for rhodium was expected to increase by 1,700 kg to 17,500 kg in 2000, boosted by higher vehicle production, tighter emissions standards, and changes in the PGM mix in autocatalysts. Stage III European emissions legislation came into force in 2000, leading to an increase in average rhodium loadings. Although European Union stage IV regulations will not take effect until 2005, fiscal incentives encouraged some car manufacturers to fit automobiles with catalysts capable of meeting stricter limits much sooner. Japan also saw an increase in rhodium demand in response to new legislation. Japan's Low Emissions Vehicle regulations were imposed in October 2000, but many automakers had adopted catalysts capable of meeting the new limits ahead of this deadline. Loadings on Japanese export vehicles have also increased, in line with tightening emissions limits in Europe and the United States (Johnson Matthey plc, 2000).

### Legislation and Government Programs

In June 2000, the U.S. Defense Logistics Agency (DLA) requested the U.S. Mint to return 6,219 kg of platinum loaned in 1997 for the Mint's American Eagle Bullion program. DLA requested the return of the metal so that it could complete its fiscal year 2000 sales and prepare for its fiscal year 2001 sales. Under its Annual Materials Plan for fiscal year 2000, DLA was authorized to sell 3,888 kg of platinum. DLA was also authorized to sell the same amount of platinum in fiscal year 2001 and needs the material from the Mint to complete its sales. The terms of the 1997 agreement between the Mint and DLA required that a like amount of platinum of similar quality be returned before the agreement expires in 2003. If the occasion should arise, as it did in June 2000, the mint was required to return the metal upon 30 days notice. DLA requested that 50% of the material be returned by March 31, 2000, and the balance returned by June 30, 2000, so that the agency would be positioned to offer the material for sale by October 1, 2000 (Platt's Metals Week, 2000a). On August 25, DLA announced that the Annual Materials Plan for palladium would be increased by 3,110 kg for fiscal year 2000 and the Defense National Stockpile Center reactivated its PGM sales program on August 28, 2000.

### Production

World mine production of PGM decreased by about 3%, to 365,000 kg compared with 376,000 kg in 1999. In South Africa, the world's leading producer, PGM output decreased by about 11% to 201,800 kg. Production in Russia, the world's second largest producer, was estimated to have increased by 11% to 128,100 kg.

The Stillwater Mining Co. operates the Stillwater Mine in Nye, MT. The company is the only primary palladium-platinum producer in the United States. In 2000, the Stillwater Mine reported production of 13,400 kg of palladium and platinum,

over 5% higher than production in 1999. Of the 13,400 kg produced, palladium accounted for 10,300 kg, and platinum accounted for 3,110 kg. Mine production is defined by Stillwater as the quantity of PGM contained in a concentrate at the time it was shipped to the smelter. The company milled 617,000 metric tons of ore in 2000, 2% less than in 1999. The mill head grade was 21.5 grams per metric ton (g/t) of combined palladium and platinum in 2000, compared with 20.5 g/t in 1999. East Boulder, Stillwater's new mine, changed its focus in 2000 from surface construction to underground development. The concentrator and other surface facilities were essentially complete. During 2001, Stillwater expects to process a limited amount of ore through the concentrator from ore removed during the course of mine development work. Stillwater expected that the East Boulder Mine would move to commercial production during 2002 (Stillwater Mining Co., 2001, p. 9-14).

Stillwater operates a smelter and base metal refinery at its metallurgical complex in Columbus, MT. Expansions at the smelter were completed in 1999 and the smelter completed its first full year of operation in 2000. The smelter recorded a 12% increase in PGM produced, while reducing sulfur dioxide emissions by 67% compared with that of 1999. In the fourth quarter of 2000, the smelter shipped 445 kg of platinum and palladium contained in a matte, a quarterly record for the company.

Stillwater's automobile catalyst recycling effort also continued in 2000. The smelter processed more than 2 metric tons per day of spent autocatalyst in 2000, containing 929 kg of palladium and platinum, more than double the 390 kg processed in 1999. Spent autocatalysts typically contain three parts platinum to one part palladium, reflecting the metals use in older clean-air technology. This ratio will shift in time as the palladium-dominated catalysts used in 1999-2000 begin to be recycled.

In 2000, Stillwater completed construction of a copper-dissolve-pressure-leach and selenium/tellurium removal circuits at its base-metal refinery. The function of the copper-dissolve-pressure-leach is to increase PGM production and provide ideal copper solution feed to the selenium/tellurium removal circuit. The selenium/tellurium circuit, as the name implies, removes selenium and tellurium from the copper solution that feeds a copper electrowinning circuit. The refining process removes small amounts of copper, gold, nickel, and rhodium to produce a final palladium-platinum product. A nickel sulfate crystallizer was also in the final stages of construction. Stillwater expected this circuit to be completed in the first half of 2001. The crystallizer will allow the company to ship its nickel sulfate byproduct as a solid rather than a liquid. The nickel sulfate is shipped to Canada for further refining. The final palladium-platinum product is shipped to California and New Jersey where it is converted into palladium and platinum sponge. The sponge is then sold, primarily for use in catalytic converters (Stillwater Mining Co., 2001, p. 18-21).

Proven and probable reserves of the company are contained in the J-M Reef in southern Montana. The average ratio of palladium to platinum contained in the reef is 3.3 to 1. At yearend 2000, proven and probable reserves, including the Stillwater and East Boulder Mines, contained 786,000 kg of palladium and platinum in 35.6 million metric tons (Mt) of ore grading 22.1 g/t of combined palladium and platinum.

Secondary production of PGM from spent autocatalysts and other PGM-bearing waste materials yielded increased amounts

of metal in 2000 when compared with that of 1999. Large amounts of platinum contained in catalytic converters from end-of-life vehicles helped push global recovered platinum from this source to 14,600 kg in 2000 versus 13,100 in 1999. U.S. secondary production of platinum was estimated at about 12,000 kg. Increasingly stringent regulations designed to reduce emissions prompted higher loadings of palladium in autocatalysts. Increased demand and short supplies prompted sharply higher prices and an attendant increase in the secondary recovery of palladium. About 7,200 kg were recovered globally in 2000, up from slightly more than 6,000 kg in 1999. Johnson Matthey reported that global recovery of rhodium from spent autocatalysts reached 2,430 kg in 2000, up 20% from 2,020 kg in 1999. The United States accounted for most of the increase, although significant increases were reported for Europe and Japan (Johnson Matthey plc, 2001, p. 49-52).

## Consumption

In 2000, total world demand for platinum was up only slightly from 1999 and was estimated by Johnson Matthey at about 174,000 kg (Johnson Matthey plc, 2001, p. 48). U.S. apparent consumption of platinum was about 50,000 kg, or 28% of world demand. U.S. industry consumed an additional 12,000 kg of platinum that had been recovered from spent autocatalysts. World demand for palladium was down 3% from a near record 292,000 kg in 1999 to 277,000 kg in 2000. U.S. apparent consumption of palladium was estimated at 104,000 kg or 38% of world demand.

**Platinum.**—In 1999, demand for platinum by U.S. automakers declined for the third consecutive year, despite increased auto sales in the United States and Canada. Platinum demand declined because PGM loadings on catalytic converters had shifted toward palladium-rich catalysts. In 2000, demand for platinum in autocatalysts accounted for about 33% of total demand, growing by 14% to 57,200 kg. This was the first increase in 4 years for this sector of platinum demand. The increase was driven by automakers' efforts to reduce the palladium content in catalyst formulations and the move in Europe to diesel engines as new emissions standards are introduced. Platinum loaded autocatalysts are more efficient than palladium loaded catalysts on diesel engines. In the United States, there was a return to the use of platinum catalysts for gasoline engines. Automobile manufacturers were under increasing pressure to reduce the amount of emissions from vehicles. In order to meet the new standards and keep prices down, automakers needed to reduce their dependence on the more expensive palladium.

Global demand for platinum in jewelry declined for the first time in 16 years, down by 1% to 88,300 kg. Increases of 15% in the United States, 16% in China, and a steady growth in Europe were more than offset by a 20% decline to 33,000 kg in Japan (Mining Journal, 2001a).

**Palladium.**—High prices had a negative impact on demand for palladium which declined by 9.7% to 277,000 kg. Higher prices had the greatest impact on the automobile sector where demand fell 12% to 161,000 kg. The electronics industry was also hit by high palladium prices, however, producers of multilayer ceramic capacitors (MLCC) were successful in replacing palladium with lower priced nickel and silver. Consequently, the proportion of MLCCs using palladium decreased from 62% in 1999 to 46% in 2000. Nevertheless,

MLCC output rose by 47% in 2000, offsetting palladium's loss of market share. As a result, demand from the electronics sector increased by 5% to 64,400 kg. Although overall demand was down in 2000, it is important to note that supply was down as well, from 252,000 kg to 246,000 kg, mainly due to lower Russian sales. Global demand exceeded global supply by 14,900 kg (CRU Quarterly Market Service Report, 2001).

**Rhodium.**—The rhodium market was characterized by strong consumer demand and tight supplies. Demand for rhodium increased in all regions, driven by the need to meet tougher emission standards in Europe, Japan, and the United States. Rhodium was added to some palladium-only catalyst systems to meet more rigorous emissions control standards, as automakers attempted to minimize their dependence on palladium. New legislation coming into effect over the next few years is directed at hydrocarbon emissions for which palladium is particularly effective as a catalyst. The addition of rhodium to palladium-only catalyst, however, helps lower the overall PGM loading. Autocatalysts accounted for more than 90% of demand. Rhodium's other principal applications were in the manufacture of specialty chemicals and the glass industry. Sales to the glass industry, 1,300 kg, were strong in 2000, driven by the construction of new plants to manufacture the high-quality thin glass used in liquid crystal displays. Johnson Matthey estimates world demand for rhodium in 2000 at about 25,000 kg, 98% of which was used in autocatalysts. The amount of rhodium recovered from scrapped catalytic converters increased 20% to 2,400 kg, more than one-half of which were removed from cars in the United States, where rhodium levels in autocatalysts increased significantly in the early 1990s.

**Iridium and Ruthenium.**—Demand for ruthenium remained strong in 2000 as it was used in a new process that manufactured feed stock for the production of solvents and synthetic fibers. Consumption of ruthenium in catalysts used in the Kellogg advanced ammonia process was also strong in 2000. The process required less stringent operating conditions than traditional base metal catalysts, and thus substantially reduced energy costs.

Continuing growth in the electronics industry was the driving force in increased demand for both iridium and ruthenium. The largest consumption of ruthenium was in the production thick film paste used in the manufacture of resistors. Increased production of resistors, for use in consumer electronics, was somewhat offset by the miniaturization of electronic components.

Reduced sales of iridium automobile and chemical-process catalysts were more than offset by strong demand for crucibles for growing synthetic crystals, especially single crystal sapphires. During 2000, there was significant growth in the demand for mobile phones with production of these devices growing by almost 50%. This generated a comparable demand for lithium-based crystals, which are used in surface acoustic wave filters to prevent signal interference between individual phones. These crystals are grown in iridium crucibles. There was a significant increase in production capacity of these crystals in 2000 which led to an almost threefold increase in iridium consumption in this application.

The electrochemical industry accounts for significant portions of total demand for iridium and ruthenium. Electrodes coated with either iridium or ruthenium or a mixture of iridium and ruthenium are used in a number of electrochemical processes. The most important of these is the chlor-alkali process which is

used to produce chlorine and caustic soda from brine.

## Prices

Russian shipments of PGM were delayed again in 2000, exerting upward pressure on PGM prices. Concern about supplies continued to run high as late as May when Russia resumed sales on a spot basis. Russia had offered spot palladium in the first few weeks of 2000 and resumed offering spot platinum in May. Even though Russia returned to the spot market, it remained silent about whether it would supply PGM under long-term contracts. Russia supplies more than 60% of the world's palladium and about 25% of the world's platinum.

**Palladium.**—The palladium price set an alltime record in 2000, ending the year at an average of \$691.84 per ounce. After starting the year at \$437, the price began to rise later in January, stimulated by strong demand and a shortage of the metal from Russia. Price increases steepened in February, reaching \$815 on February 22. This gain was mostly due to panic buying on the Tokyo Commodities Exchange (TOCOM). On February 23, TOCOM suspended trading of palladium futures and froze prices to allow the orderly liquidation of contracts. On February 24, the palladium price fell abruptly below \$700. The price decline was short lived, owing to continued shortages of physical metal, which supported a palladium price above \$700 for much of March. Prices began to sink again following rumors of imminent shipments from Russia, falling to around \$570 on March 31. Prices began to climb in April, encouraged by strong physical demand, an increase in lease rates, and the cancellation of TOCOM restrictions on palladium contracts. The rally continued, culminating on August 2, when the price of palladium reached a new high of \$865. The rally ended quickly as prices fell to \$720 on August 28. Palladium prices made even more dramatic gains in December when it was reported that RAO Norilsk Nickel had exhausted its palladium export quota for 2000 and that the Russian Government had no plans to sell more metal. The price climbed rapidly above \$900, finally reaching a record high of \$985 on December 27.

**Platinum.**—Platinum prices advanced strongly in 2000, rising from a low of \$416 per ounce on January 6 and closing the year at an average \$549.31 per ounce. The low was in response to reports that the President of Russia had signed a revision to a clause in the 1999 budget bill that provided the legal framework for the resumption of platinum exports. Platinum exports had been delayed since April 1999. Prices began to rise during the middle of January as it became clear that, despite the revision, shipments from Russia would not resume immediately. Prices continued to climb through February, reaching an 11-year high of \$573 on February 17. Prices fell to around \$460 in the first week of March and experienced wide swings in April before settling between \$470 and \$570 through July. Prices increased sharply again in August, driven by lack of shipments from Russia and lifted by palladium's record price. On August 2, the platinum price reached \$615, its highest level since 1988. The rally ended abruptly as reports circulated that Norilsk Nickel expected to ship metal to Japan in September or October. Prices made gains in September, rising above \$600 on several occasions, but began to weaken again in mid-September, falling to a low of \$582 on September 26. Prices began to rise again in early November reaching \$625 on the 28th. Again the increase was driven by a shortage of physical metal supplies from

Russia. The increases continued into December with prices reaching \$625 on the 13th and again on the 28th, its highest price since August 1987. Prices continued to trade above \$600 for the remainder of the year.

**Iridium, Rhodium, and Ruthenium.**—Strong consumer demand and short physical supplies pushed the price of rhodium to an 8-year high of \$2,600 per ounce in August 2000. Increased sales from Russia caused prices to weaken to \$1,625 in October, before recovering to \$2,025 at yearend. Industrial buying propelled the price of ruthenium to a high of \$170 per ounce in August, but iridium was unchanged at \$415 per ounce throughout the year (Johnson Matthey plc, 2001, p. 45-46).

## Trade

In 2000, U.S. net import reliance as a percentage of apparent consumption was estimated at 89% for palladium and 83% for platinum. South Africa accounted for 64% of refined platinum and 12% of refined palladium imports; Russia accounted for 51% of refined palladium and 3% of refined platinum imports. Palladium imports decreased 4% to 182,000 kg from 189,000 kg in 1999; platinum imports were down 25% in 2000 to 94,000 kg from 125,000 kg in 1999. U.S. exports were 58,600 kg of palladium, 25,000 kg of platinum, and small amounts of other PGM.

## World Review

**Russia.**—Russian sales of platinum and rhodium increased in 2000 following the resolution of policy issues that had prevented exports for much of 1999. The policy restricted PGM exports to authorized "State Organs." Russia's sole PGM exporter, Almazjuvelirexport, did not fit this description and neither did any other Russian organization (Platt's Metals Week, 2000c). Palladium sales were less affected in 1999 because Norilsk Nickel, Russia's primary PGM producer, had been given a 10-year quota and export license for its product. Although Russia does not publish its PGM statistics, it is generally accepted by the industry that Norilsk Nickel has an annual output of 20 to 22 metric tons per year (t/yr). Norilsk has an annual quota, authorized by the Government, to export its platinum (also palladium and rhodium), and it receives the world market value from buyers. This policy does not apply to other Russian producers. Koryakgeoldobycha (KGD), Russia's leading alluvial producer, and other alluvial producers concentrated in the Russian Far East account for about 10 t/yr of PGM output (Platt's Metals Week, 2000b). Gokhran, the State metal stocking agency, has a pricing policy that offered alluvial producers 20% to 30% less than the international market value for their metal. This discrepancy led to a dispute between the alluvial platinum producers and Gokhran, as the producers refused to sell at Gokhran's price. KGD began stockpiling its platinum rather than sell to Gokhran. KGD reportedly has a large stockpile unsold from 2000 and plans to hold up to 2,200 kg of platinum while it waits for a change in State pricing policy. Gokhran has not announced any changes in its pricing policy. Meanwhile, KGD planned to increase its platinum output to 4,400 kg in 2001 from 3,300 kg in 2000. The company is also asked the Government for permission to export its metal without having to go through Gokhran (Platt's Metals Week, 2000b).

**South Africa.**—Along with byproduct cobalt, copper, gold, nickel, and silver, PGM occurs in South Africa in three separate

layered reefs associated with mafic rocks in the Rustenburg Layered Suite of the Bushveld Complex in the Transvaal. The reefs are the Merensky Reef, the UG2 Chromite Layer, and the Platreef. The PGM occurs as alloyed native metals, as platinoid minerals (such as sperrylite and braggite) and in copper, nickel, cobalt, and iron sulfide minerals (such as chalcopyrite, pentlandite, and pyrrhotite).

Rustenburg Platinum Mines Ltd. (RPM), a subsidiary of Anglo American Platinum Corp., Ltd., was the largest single South African PGM producer and operated three geographically separate sections, all on the western limb of the Bushveld Complex. The other mines on the western limb are the two adjoining Impala Platinum Ltd. (Implats) Mines, Bafokeng North Mine and Wildebeestfontein South; the two Lonmin Platinum Division mines, Eastern Platinum Ltd. and Western Platinum Ltd.; and Northam Platinum Ltd. (Department of Minerals and Energy, 1997, p. 34-36).

In 2000, South Africa produced about 201,800 kg of PGM, about 11% less than the 224,600 kg produced in 1999. Production fell because of a combination of heavy rainfall and strike actions at Anglo American Platinum, the world's leading producer of PGM. Production of platinum at Anglo Platinum fell by 4,700 kg to 58,200 kg. Implats' production was also impacted by the heavy rains. Although mining itself was unaffected by the poor weather, the collapse of a conveyor belt disrupted mineral processing and was the main reason for a 2,330 kg drop in output to 31,100 kg. Lonmin, plc, which is further east, and was less affected by the inclement weather, increased production by 4% to 20,200 kg. Northam Platinum Ltd. output was virtually unchanged at 5,510 kg while Kroondal, which completed its first year of full production, produced 2,000 kg of platinum (Mining Journal, 2001b).

The positive outlook for PGM markets resulted in a number of expansion plans by South African producers. Anglo American Platinum announced that it would invest R12 billion to expand output from 62,200 kg to 109,000 kilograms per year (kg/yr) of refined platinum by 2006. Of the announced expansions, those at the Amandelbult Mine and Lebowa Mine, with a combined output of 3,330 kg, were completed in 2000. A new mine, costing R1.3 billion in Maandagshoek, with a production capacity of about 5,000 kg/yr of platinum, was scheduled to come into operation by 2004 (Metal Bulletin, 2000a).

Implats reopened the Crocodile River Mine and opencast mining began in December 2000. At full production, the mine's platinum output reportedly will be 1,600 kg/yr. In December 2000, the company announced its purchase of 100% of Platexco, Inc., a Canadian listed company that owns the Winnaarshoek property on the eastern limb of the Bushveld Complex. Mining is expected to begin in 2002, and full production of 6,220 kg/yr of platinum is planned for the end of 2003 (Mining Journal, 2001).

The Kroondal platinum mine in South Africa planned to triple production of PGM to 15,900 kg/yr in a joint venture with Implats. Kroondal started commercial production in September 1999, and reached full production within 3 months. Under the proposed joint venture, RPM will contribute portions of its UG2-reef mineral rights, while RPM will contribute the existing mine and plant as well as its own mineral rights. The mineral rights contribution from RPM will lift the projects *in situ* resources to nearly 60 Mt of UG2 ore, and is designed to ensure a mine life of 13 years. The partners intend to expand

the existing plant from its current design capacity of 5,290 kg of PGM (3,110 kg/yr of platinum 1,680 kg of palladium, and 498 kg of rhodium) to 7,930 kg/yr of PGM per year, including 4,670 kg of platinum. A new concentrator, which will be built next to the mine's eastern decline, will have a similar capacity, boosting Kroondal's annual output by 1,590 kg (9,330 kg platinum) from a total feed of 5.4 Mt of ore (Mining Journal, 2000).

**Zimbabwe.**—In 1999, Zimbabwe produced about 7,200 kg of PGM but its major primary producer, Hartley Platinum, was closed in June 2000. Following the closure of Hartley, Zimbabwe's only primary production came from the small Mimosa Mine, with an output of about 600 kg/yr. Mining investments in Zimbabwe have often been discouraged by political and economic instability. In 2000, there was the prospect of a new framework for investing in platinum mining, with the Government expected to relax foreign exchange restrictions and reduce the tax rate on platinum operations. An improved climate for investment will likely lead to funding for the development of the Ngezi opencast mine. Zimbabwe Platinum Mines Ltd. (Zimplats), which owns the mine, reported that it had carried out a 3-month trial mining program at Ngezi and full-scale mining would begin as soon as new mining legislation is passed. The Ngezi platinum mine is expected to produce a minimum 2 million metric tons per year (Mt/yr) of unrefined ore. A 2 Mt/yr mining rate is considered a minimum and, if the project proceeds, the tonnage is expected to increase. The mine processing plant would consist of a conventional crusher, mill, concentrator, and dryer. Dried metal in sulfide concentrate would be the mine end-product for sale or toll refining of the contained palladium, platinum, copper, nickel, and gold. Zimplats is also interested in restarting activities at the closed Hartley platinum mine and an agreement has been reached by Zimplats and the Zimbabwe Government on the takeover. Zimplats owned a 33.3% share in Australia-based Broken Hill Proprietary Co. Ltd. before the company closed Hartley (Metal Bulletin, 2000b).

## Current Research and Technology

### *Palladium-Silver Resistors for High-Power*

**Applications.**—With the advent of ruthenium-based resistors, the use of palladium-silver resistors on thick film circuits was all but discontinued until the 1990s when demand in new niche applications led to their resurgence. The relatively high power-handling of these metallic resistors enabled them to be used as secondary lightning surge protection devices for communications equipment. For such applications, low-value compositions, about 0.1 to 1 ohm-milimeter<sup>2</sup>/centimeter ( $\Omega/\square$ ), are printed in a serpentine configuration, typically about 1.27-centimeter (cm) x 2.54-cm area, to fabricate 10-to 300-ohm components. More recently, the resistance range of interest to circuit designers has shifted down to as low as 5.6 ohms. Although it is possible to design 5.6-ohm resistors using the existing 0.1  $\Omega/\square$ -inks, the resulting area would be quite large, resulting in bulky circuits. This points to a need for low resistivity inks with more robust power handling capability. A new series of palladium-silver inks with resistivity as low as 0.015  $\Omega/\square$  have been developed. The palladium-silver resistors can extend the reach of thick film technology into high power applications that were formerly reserved for bulky wire-wound resistors (Printed Circuit Design, 2000).

**Advances in PEM Fuel Cells.**—Under terms of an agreement

between Johnson Matthey and James Cropper plc, Technical Fibre Products, the advanced composites subsidiary of James Cropper, will provide key components in Johnson Matthey's new Membrane Electrode Assembly (MEA) products for fuel cells. The agreement centers upon the development of carbon composite substrates to be used to support the [platinum] catalysts and other MEA components that form the heart of polymer electrolyte membrane (PEM) fuel cells. There now seems little doubt that fuel cells will emerge as a major propulsion system for cars and trucks within the next 5 to 10 years and will generate an additional demand for about 500,000 kg of platinum. Offering an attractive driving range and quick refueling, fuel cells may displace various high-energy battery options that are now being investigated to meet zero emission requirements on vehicles in the United States (Platt's Metals Week, 2000b).

Currently, fuel cell power units cost about 10 times that of conventional gasoline engines and use hydrogen (liquid or gas) as the primary fuel. Most researchers in the field, however, have begun investigating alternatives to pure hydrogen as the primary fuel because of difficulties associated with its storage and distribution and are considering the use of methanol. Methanol is low in carbon and rich in hydrogen. Fuel cell power systems fueled by methanol would require a reformer subsystem to convert methanol to the hydrogen required. One disadvantage of methanol is that, unlike the use of pure hydrogen, water would not be the only exhaust pipe emission; carbon monoxide, carbon dioxide, and nitrogen oxides would also be emitted (Metal Bulletin Monthly, 2000). In a related project, researchers at NASA's Jet Propulsion Laboratory, Pasadena, CA, have developed an improved method of fabricating PEM-electrode structures for methanol fuel cells. The procedure involves the use of improved sprayers to deposit inks containing [platinum] catalytic metals onto proton exchange membranes of perfluorosulfonic acid polymers. The inks usually contain the catalytic metal (platinum for the cathode and a mixture of platinum and ruthenium for the anode), a proton conducting ionomer solution, water, and isopropanol, with perhaps a small amount of a polytetrafluoroethylene-based additive. In experiments, the performances of fuel cells containing electrode structures made by the new method were found to be comparable to fuel cells made by older methods. The amount of catalyst used in the new method, however, ranged from 1 to 2 milligrams per square centimeter ( $\text{mg}/\text{cm}^2$ ), whereas the amounts used in the older methods were typically about  $4 \text{ mg}/\text{cm}^2$ . The new method is suitable for mass production and may be a significant step toward commercialization and reducing the cost of fuel cells (NASA Tech Briefs, 2000).

***New Fuel Cell May Eliminates Need for Platinum.***—The most commonly used fuel cells contain platinum catalysts to convert conventional fuels into hydrogen fuel. Researchers in Japan have designed a solid-oxide fuel cell (SOFC) that advances the prospect of using fuel cells for onboard power generation in transportation applications that require the use of conventional fuels. The system consists of only one gas chamber in which both the anode and cathode are exposed to the same mixture of fuel and air. This design eliminates the need for a reformer, which uses a platinum catalyst, to convert hydrogen rich hydrocarbons to hydrogen. SOFCs have several advantages over more commonly used PEM fuel cells. For example, SOFCs do not require conversion of hydrocarbons to

hydrogen, and SOFCs have a lower fabrication cost because they do not require the use of platinum catalysts. In addition, the anode in SOFCs is not poisoned by carbon monoxide, a major problem with PEM fuel cells that decrease their performance when conventional fuels are used directly. The new SOFC design also is compact and takes up less space than PEM cells. That advantage, combined with no need for an onboard reformer, makes the SOFC system attractive for transportation applications (Environmental Science & Technology, 2000, p. 419A).

## Outlook

Despite the forecast of reduced world economic activity, demand for platinum is expected to continue to increase. Future demand is expected to be influenced by the automobile industry as sales of diesel powered vehicles increase in Europe and Japanese and U.S. automakers add platinum to autocatalyst on gasoline engines in an effort to reduce their dependence on palladium. Jewelry manufacturing, which accounts for a major portion of platinum demand, is expected to weaken in 2001. Weak economies in Japan coupled with high prices over the past year caused demand at the lower end of the jewelry market to shift to cheaper materials, such as white gold. Demand for platinum jewelry in China was on the rise, increasing 22% to 34,200 kg in 2000. China, second largest jewelry consuming market after Japan, imports most of its demand for platinum and may strengthen controls over imports to discourage illegal trading (China Metal Market, 2001). Demand for platinum in industrial applications is expected to rise but at a slower rate than in the previous 2 to 3 years owing to a decline in world economic conditions.

Rising palladium prices in 1999–2000 led to increased substitution of base metals for palladium in the electronics and dental industries, and automakers made clear their intentions to reduce dependence on the metal. Despite substitutions and further loss of market share in multilayer ceramic capacitors, palladium demand actually increased in this sector. The electronic device market appears to be in a downturn and electronic component manufacturers are beginning to cut back production. Thus, demand for palladium from this sector will likely fall in the next 1 to 2 years and palladium prices will drop back to historical levels.

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TABLE 1  
SALIENT PLATINUM-GROUP METALS STATISTICS 1/

(Kilograms metal content, unless otherwise specified)

	1996	1997	1998	1999	2000
<u>United States:</u>					
<u>Mine production:</u>					
Palladium 2/	6,100	8,430	10,600	9,800	10,300
Value	thousands \$25,600	\$49,900	\$98,500	\$114,000	\$228,000
Platinum 2/	1,840	2,610	3,240	2,920	3,110
Value	thousands \$23,500	\$33,300	\$39,000	\$35,600	\$69,200
<u>Refinery production:</u>					
Palladium	NA	NA	NA	14,400	13,500
Value	thousands NA	NA	NA	\$168,000	\$224,000
Platinum	NA	NA	NA	14,000	17,500
Value	thousands NA	NA	NA	\$172,000	\$308,000
<u>Imports for consumption, refined:</u>					
Iridium	1,810	1,860	1,950	2,250	2,700
Osmium	NA	54	71	23	133
Palladium	146,000	148,000	176,000	189,000	181,000
Platinum, includes waste, scrap and coins	75,800	77,300	96,700	125,000 r/	94,000
Rhodium	9,650	14,400	13,500	10,300 r/	18,200
Ruthenium	15,600	11,500	8,880	11,400	20,900
<u>Exports, refined:</u>					
Iridium, osmium, and ruthenium (gross weight)	122	574	905	851	1,480
Palladium	26,700	43,800	36,700	43,800 r/	58,600
Platinum	12,700	23,000	14,300	19,400	25,000
Rhodium	187	282	811	114	797
<u>Stocks, National Defense Stockpile, December 31:</u>					
Iridium	920	920	920	784	784
Palladium	39,300	39,300	38,800	28,200	19,000
Platinum	14,100	14,100	13,700	7,060	5,190
<u>Price, average per troy ounce:</u>					
Iridium 3/	\$74.00	\$205.42	\$441.85	\$411.40	\$415.00
Palladium 4/	\$130.39	\$184.14	\$289.76	\$363.20	\$691.84
Platinum 4/	\$398.07	\$396.59	\$374.61	\$378.94	\$549.31
Rhodium 4/	\$308.30	\$298.00	\$619.83	\$904.35	\$1,990.00
Ruthenium 3/	\$47.56	\$40.51	\$47.95	\$40.70	\$129.76
Employment	500	550	620	954 r/	1,290
World, mine production	324,000	333,000	348,000 r/	376,000 r/	365,000 e/

e/ Estimated. r/ Revised. NA Not available.

1/ Data are rounded to no more than three significant digits; except for prices.

2/ Source: Stillwater Mining Co., 2000 10-K report, p. 80.

3/ Price data are annual averages of daily Engelhard unfabricated quotations published in Platts Metals Week.

4/ Price data are annual Engelhard unfabricated quotations published in Platts Metals Week.

TABLE 2  
U.S. IMPORTS FOR CONSUMPTION OF PLATINUM-GROUP METALS, BY COUNTRY 1/

(Kilograms metal content, unless otherwise specified)

Country	Platinum grain and nuggets		Platinum sponge		Other unwrought platinum		Platinum, other		Platinum waste and scrap		Platinum coins	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
	6,100	\$76,300	74,300 r/	\$738,000 r/	7,820	\$96,000	16,500	\$187,000	19,700	\$47,100 r/	171 r/	\$2,260 r/
1999												
2000:												
Australia	--	--	--	--	--	--	144	2,340	59	1,110	2	106
Belgium	129	1,920	4,910	83,500	122	1,560	--	--	--	--	--	--
Brazil	--	--	--	--	--	--	301	4,080	418	2,830	--	--
Canada	20	336	31	609	33	601	878	15,100	9,350	12,800	20	330
Chile	--	--	--	--	--	--	351	4,740	--	--	--	--
China	--	--	--	--	5	69	--	--	4	83	(2/)	5
Colombia	3	42	--	--	221	3,620	--	--	(2/)	33	--	--
Estonia	--	--	--	--	32	548	--	--	--	--	--	--
France	--	--	12	188	--	--	2	19	135	4,150	--	--
Germany	669	10,200	4,370	77,200	378	6,530	2,430	32,300	904	13,400	2	36
Honduras	--	--	--	--	--	--	--	--	--	--	--	--
Hong Kong	2	35	--	--	--	--	123	1,930	327	12,800	--	--
India	--	--	--	--	--	--	3	29	--	--	--	--
Indonesia	--	--	--	--	2	31	--	--	102	5,230	--	--
Ireland	--	--	--	--	39	742	2	24	--	--	--	--
Israel	--	--	(2/)	3	377	8,690	--	--	18	535	--	--
Italy	19	300	439	6,870	18	345	1	21	80	1,950	--	--
Japan	154	2,550	175	3,030	18	200	593	10,600	3	1,060	--	--
Korea, Republic of	19	699	--	--	--	--	1	4	91	4,720	--	--
Malaysia	--	--	--	--	--	--	13	157	7	168	--	--
Mexico	34	490	3	50	--	--	2	25	171	5,190	--	--
Netherlands	--	--	--	--	--	--	58	423	--	--	--	--
Norway	--	--	171	2,980	--	--	--	--	--	--	--	--
Peru	(2/)	6	--	--	--	--	--	--	5	116	--	--
Philippines	--	--	--	--	--	--	--	--	11	188	--	--
Poland	--	--	--	--	32	256	--	--	--	--	--	--
Russia	--	--	2,290	42,800	632	10,900	--	--	--	--	--	--
Saudi Arabia	--	--	4,630	7,960	--	--	--	--	1	25	--	--
Singapore	--	--	--	--	--	--	20	260	(2/)	43	--	--
South Africa	1,260	21,800	43,200	706,000	907	17,100	106	1,840	6	2,750	--	--
Spain	--	--	--	--	--	--	328	3,590	--	--	--	--
Sweden	1	8	--	--	--	--	--	--	--	--	--	--
Switzerland	92	1,820	363	7,120	737	13,400	1,260	15,200	--	--	--	--
Taiwan	--	--	--	--	2	17	2	34	66	2,010	--	--
Thailand	--	--	1	10	6	109	--	--	--	--	--	--
United Kingdom	146	2,660	7,370	114,000	304	5,470	869	18,000	201	13,900	3	51
Other	3	31	--	--	2	45	--	--	93	947	1	38
Total	2,550	42,900	68,000	1,050,000	3,870	70,200	7,480	111,000	12,100	86,000	27	565

See footnotes at end of table.

TABLE 2--Continued  
U.S. IMPORTS FOR CONSUMPTION OF PLATINUM-GROUP METALS, BY COUNTRY 1/

(Kilograms metal content, unless otherwise specified)

Country	Unwrought palladium		Palladium, other		Iridium 3/		Unwrought osmium		Unwrought ruthenium		Rhodium 4/	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
1999	165,000	\$1,810,000	24,100	\$275,000	2,250 r/	\$25,100	23	\$272	11,400	\$14,700	10,300 r/	\$274,000 r/
2000:												
Australia	--	--	--	--	--	--	--	--	--	--	525	33,100
Belgium	11,400	236,000	88	2,690	--	--	--	--	--	--	1,160	69,400
Brazil	223	5,370	--	--	--	--	--	--	--	--	3	123
Canada	3,640	66,100	55	685	42	210	--	--	1	5	14	1,970
Chile	--	--	35	646	--	--	--	--	--	--	--	--
China	1,630	20,700	192	1,580	--	--	--	--	--	--	18	915
Colombia	--	--	--	--	--	--	--	--	--	--	--	--
Estonia	145	3,350	--	--	--	--	--	--	--	--	16	710
France	--	--	1	4	48	785	--	--	89	281	25	1,930
Germany	4,420	87,300	2,630	49,300	118	1,540	6	92	971	3,130	361	17,800
Honduras	98	302	--	--	--	--	--	--	--	--	--	--
Hong Kong	--	--	--	--	--	--	--	--	--	--	--	--
India	--	--	--	--	--	--	--	--	--	--	--	--
Indonesia	--	--	--	--	--	--	--	--	--	--	--	--
Ireland	--	--	16	306	--	--	--	--	12	11	--	--
Israel	6	12	--	--	--	--	--	--	--	--	--	--
Italy	855	14,500	691	11,400	3	50	--	--	(2/)	2	(2/)	25
Japan	7,190	69,100	312	1,890	3	46	--	--	1	4	52	3,190
Korea, Republic of	24	425	2	15	--	--	--	--	--	--	11	886
Malaysia	--	--	--	--	--	--	--	--	--	--	--	--
Mexico	16	76	--	--	--	--	--	--	--	--	2	24
Netherlands	--	--	2	22	--	--	--	--	36	124	--	--
Norway	2,410	44,900	--	--	--	--	--	--	--	--	--	--
Peru	--	--	--	--	--	--	--	--	--	--	--	--
Philippines	--	--	--	--	--	--	--	--	--	--	--	--
Poland	--	--	--	--	--	--	--	--	--	--	--	--
Russia	73,600	1,600,000	18,900	238,000	--	--	--	--	995	4,990	9,110	347,000
Saudi Arabia	--	--	--	--	--	--	--	--	60	309	--	--
Singapore	1	27	2	47	--	--	--	--	--	--	--	--
South Africa	20,400	409,000	1,210	24,000	1,470	11,000	127	1,040	17,700	37,300	5,800	300,000
Spain	--	--	--	--	--	--	--	--	--	--	--	--
Sweden	331	5,890	--	--	--	--	--	--	--	--	--	--
Switzerland	8,200	205,000	3,370	26,500	4	30	--	--	--	--	6	197
Taiwan	--	--	(2/)	13	--	--	--	--	--	--	(2/)	3
Thailand	--	--	--	--	--	--	--	--	--	--	--	--
United Kingdom	19,100	342,000	340	6,500	1,020	13,700	--	--	1,110	3,500	1,080	73,800
Other	--	--	--	--	--	--	--	--	--	--	--	--
Total	154,000	3,110,000	27,900	364,000	2,700	27,400	133	1,130	20,900	49,600	18,200	851,000

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

3/ Unwrought and other forms of iridium.

4/ Unwrought and other forms of rhodium.

TABLE 3  
U.S. EXPORTS OF PLATINUM-GROUP METALS, BY COUNTRY 1/

(Kilograms metal content, unless otherwise specified)

Country	Palladium		Platinum		Platinum, waste and scrap		Iridium, osmium ruthenium		Rhodium	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
		(thousands)		(thousands)		(thousands)		(thousands)		(thousands)
1999	43,800	r/ \$271,000	r/ 19,400	\$200,000	7,660	\$320,000	851	\$11,200	114	\$5,310
2000:										
Argentina	3	16	4	26	--	--	--	--	--	--
Australia	462	6,070	422	3,670	--	--	1	7	(2/)	38
Austria	--	--	21	80	--	--	1	3	--	--
Bahamas, The	--	--	--	--	(2/)	8	--	--	--	--
Belarus	55	310	--	--	--	--	--	--	--	--
Belgium	954	12,000	116	1,690	72	4,410	3	17	8	316
Bermuda	2	3	2	9	--	--	--	--	--	--
Bolivia	--	--	--	--	--	--	1	32	--	--
Brazil	68	446	490	6,390	--	--	(2/)	10	--	--
Canada	6,440	39,800	1,990	25,800	410	13,800	52	1,240	64	5,070
Cayman Islands	2	8	18	224	--	--	--	--	--	--
Chile	42	62	713	4,050	--	--	--	--	--	--
China	1,590	20,600	23	281	3	100	(2/)	6	10	245
Colombia	--	--	3	39	--	--	--	--	--	--
Costa Rica	--	--	4	53	--	--	--	--	--	--
Cyprus	4	20	--	--	--	--	(2/)	7	--	--
Denmark	65	316	21	118	--	--	17	104	--	--
Dominican Republic	15	23	3	31	--	--	--	--	--	--
El Salvador	3	10	--	--	--	--	--	--	--	--
Finland	7	58	29	172	--	--	--	--	--	--
France	393	3,760	438	5,470	(2/)	4	85	1,390	--	--
French Polynesia	2	5	--	--	--	--	--	--	--	--
Germany	4,680	53,300	2,290	29,200	3,110	61,400	72	645	51	3,110
Greece	14	32	5	9	--	--	--	--	--	--
Guatemala	1	3	--	--	--	--	--	--	(2/)	9
Haiti	3	12	--	--	--	--	--	--	--	--
Hong Kong	234	722	1,200	16,200	7	309	63	848	2	362
Hungary	(2/)	3	--	--	--	--	--	--	--	--
Iceland	6	20	4	10	--	--	--	--	--	--
India	2	4	25	259	--	--	1	12	1	101
Indonesia	--	--	--	--	--	--	--	--	(2/)	8
Ireland	703	12,800	380	5,770	--	--	56	1,060	26	1,760
Israel	6,300	9,340	4	37	(2/)	7	(2/)	7	--	--
Italy	270	2,170	169	899	49	2,040	8	58	(2/)	8
Japan	10,900	127,000	3,190	48,800	435	14,800	302	1,940	280	23,200
Korea, Republic of	6,590	59,600	253	4,200	91	1,180	--	--	164	7,590

See footnotes at end of table.

TABLE 3--Continued  
U.S. EXPORTS OF PLATINUM-GROUP METALS, BY COUNTRY 1/

(Kilograms metal content, unless otherwise specified)

Country	Palladium		Platinum		Platinum, waste and scrap		Iridium, osmium ruthenium		Rhodium	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
		(thousands)		(thousands)		(thousands)		(thousands)		(thousands)
1999	43,800	r/ \$271,000	r/ 19,400	\$200,000	7,660	\$320,000	851	\$11,200	114	\$5,310
2000:										
Kuwait	4	33	10	70	--	--	--	--	--	--
Lebanon	--	--	--	--	--	--	--	--	(2/)	20
Luxembourg	2	3	--	--	--	--	--	--	--	--
Malaysia	36	143	102	602	--	--	--	--	--	--
Mexico	63	393	142	1,180	1	3,690	--	--	1	106
Netherlands	1,120	12,400	78	483	1	80	57	412	--	--
Netherlands Antilles	--	--	--	--	11	260	--	--	--	--
New Zealand	84	500	7	28	--	--	1	8	--	--
Norway	20	84	1	7	--	--	--	--	--	--
Peru	--	--	2	24	--	--	--	--	--	--
Philippines	40	109	18	164	--	--	--	--	--	--
Poland	1	9	(2/)	3	--	--	--	--	--	--
Romania	--	--	6	46	--	--	--	--	--	--
Saudi Arabia	3	15	15	144	9	242	--	--	(2/)	4
Singapore	97	353	43	428	--	--	--	--	--	--
Slovenia	123	418	--	--	--	--	--	--	--	--
South Africa	469	10,900	218	5,340	16	521	--	--	122	3,010
Spain	145	624	461	6,080	--	--	--	--	--	--
Sweden	103	1,790	70	459	24	1,000	6	57	--	--
Switzerland	1,370	28,800	3,250	45,600	6	155	4	22	(2/)	4
Taiwan	7,290	49,300	365	4,260	(2/)	6	(2/)	3	31	1,790
Thailand	37	357	58	345	--	--	--	--	(2/)	64
Turkey	9	49	--	--	(2/)	11	--	--	(2/)	29
United Arab Emirates	10	58	--	--	--	--	--	--	(2/)	57
United Kingdom	7,700	63,400	8,280	75,200	3,120	107,000	752	9,290	36	3,880
Uruguay	--	--	29	322	--	--	--	--	--	--
Venezuela	(2/)	3	--	--	--	--	--	--	(2/)	3
Total	58,600	518,000	25,000	294,000	7,360	211,000	1,480	17,200	797	50,800

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.

TABLE 4  
PLATINUM-GROUP METALS: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Kilograms)

Country 3/	1996	1997	1998	1999	2000 e/
<b>Platinum:</b>					
Australia e/ 4/	100	100	100	100	100
Canada	5,155	4,813	5,640	5,442	5,450
Colombia	672	409	437	440 e/	440
Finland e/	62 r/	60	50 r/	50	50
Japan 5/	816	693	533	737 r/	782 6/
Russia e/	25,000	25,000	25,000	27,000	30,000
Serbia and Montenegro e/	10	10	10	5	5
South Africa	105,000 e/	115,861	116,483	130,745	114,434 6/
United States 7/	1,840	2,610	3,240	2,920	3,110 6/
Zimbabwe	100 e/	345	2,730	479 r/	150
Total	139,000	150,000	154,000	168,000 r/	155,000
<b>Palladium:</b>					
Australia e/ 4/	400	400	400	400	400
Canada	8,082	7,545	8,905	8,592	8,600
Finland e/	182 6/	180	150 r/	150	150
Japan 5/	2,182	1,899	4,151	5,354 r/	4,712 6/
Russia e/	80,000	80,000	80,000	85,000	94,000
Serbia and Montenegro e/	50	50	50	25	25
South Africa	52,600 e/	55,675	56,608	63,600 e/	55,888 6/
United States 7/	6,100	8,430	10,600	9,800	10,300 6/
Zimbabwe e/	120	245	1,855 6/	342 r/ 6/	70
Total	150,000	154,000	163,000	173,000 r/	174,000
<b>Other platinum-group metals:</b>					
Canada e/	697	651	742	716	720
Russia e/	3,500	3,500	3,500	3,700	4,100
South Africa	30,636	24,930	27,052	30,300 e/	31,522 6/
Zimbabwe	5 e/	27	189	20 r/ e/	10
Total	34,800	29,100	31,500	34,700 r/	36,400
Grand total	324,000	333,000	348,000 r/	376,000 r/	365,000

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data have been rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through April 27, 2001. Platinum-group metal (PGM) production by Germany, Norway, and the United Kingdom is not included in this table because the production is derived wholly from imported metallurgical products and to include it would result in double counting.

3/ In addition to the countries listed, China, Indonesia, and the Philippines are believed to produce PGM, and several other countries may also do so, but output is not reported quantitatively, and there is no reliable basis for the formulation of estimates of output levels. A part of this output not specifically reported by country is, however presumably included in this table credited to Japan.

4/ PGM recovered from nickel ore that is processed domestically. PGM in exported nickel ore are extracted in the importing countries, such as Japan, and are believed to be included in the production figures for those countries.

5/ Production derived entirely from imported ores.

6/ Reported figure.

7/ A very small quantity of byproduct platinum and palladium produced from gold-copper ores was excluded.