PLATINUM-GROUP METALS

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For the third consecutive year, slow shipments from Russia in the first half of the year caused tightness in the major platinum-group metals (PGM) market that resulted in higher prices. Despite the later resumption of Russian shipments, borrowing cost remained high, briefly supporting platinum and palladium prices above $400 per ounce.

World mine production of PGM increased by about 2%, to 287,000 kilograms (kg) compared with that of 1997. South Africa, the world's largest producer, increased its palladium and platinum output by about 2%. Production in Russia, the world's second largest producer, was estimated to have been unchanged. Johnson Matthey however, estimated that Russian production was down by about 7% (Johnson Matthey, 1999, p. 5). PGM production in the United States was up by more than 25%. World mine production of the other four metals in the group remained unchanged at about 15,000 kg.

The automobile industry continued to be the major consumer of PGM. In 1998, autocatalysts accounted for approximately 51% of world palladium demand, 35% of platinum demand, and 94% of rhodium demand. Despite the overall increase in vehicle sales in 1998, demand for platinum by the automotive industry fell by 2,180 kg, to 56,900 kg, owing to the further adoption of palladium-based technology. The growing use of palladium by the automotive industry continued unabated in 1998, with palladium-rich and palladium-only autocatalysts remaining in the forefront of emission-control technology. The drive to attain increasingly lower hydrocarbon emissions to meet new standards required by U.S. and European legislation has led to the widespread use of closed-coupled catalysts with high palladium loadings. In addition, underflow catalysts, traditionally the domain of platinum-rhodium formulations, are now being replaced by their palladium counterparts. The United States leads the world in establishing strict emission standards. Beginning in 1996, automobiles were required to be in compliance with the Clean Air Act of 1990. This act required a 40% reduction in hydrocarbon and a 60% reduction in nitrogen oxides (NO_x) emissions, and durability standards of 10 years or 100,000 miles for emission-control systems. In Europe, Stage II emission standards became effective in January 1996 for new models and in early 1997 for all new vehicles. Stricter hydrocarbon standards that took effect in the United States and Europe in 1998 reinforced the move towards palladium-rich technology for gasoline cars, further eroding platinum's share of the gasoline engine market. In 1998, emission standards for diesels were relatively lenient and could be met with catalyst containing relatively low levels of platinum when compared with catalyst used with gasoline engines. Stage III limits, which were formally enacted in September 1998 and will take effect in 2000, are more demanding and could trigger significant increases in average platinum loading (Metals Monthly, 1999).

Platinum finds a variety of industrial uses owing to its unique chemical and physical properties. The electronics and the glass industries were in the forefront of demand. Growth in the personal computer market was instrumental in the increase in demand for both markets. Glass industry demand was driven by the need for high-quality glass for liquid crystal displays and cathode ray tubes, and demand in the electronic sector was driven by the need for data storage disks that are often coated with platinum alloys. The addition of a thin platinum-cobalt layer improves the data storage capabilities of the disk, allowing more data to be stored in a smaller space.

Consumer demand for iridium was strong in the first quarter of 1998, causing prices to increase sharply. The use of iridium in process catalysts has traditionally been small, although substantial quantities were being sold for a new process being adopted at several acetic acid plants. Also, a major Japanese automaker used iridium in the autocatalyst system of one of its popular models. Iridium was used in a small number of automotive spark plugs, principally in the United States.

Demand for iridium and ruthenium was driven by world consumption of chlorine, which is used in the production of polyvinyl chloride. Iridium and ruthenium are required for the coating of anodes used in the production of chlorine.

Demand for rhodium by automakers in Japan and Europe increased slightly in 1998, but North American demand was somewhat less owing to the use of palladium-only catalysts. This decline will likely be reversed in the next few years as U.S. vehicles become subjected to new high-speed certification tests. NO_x emissions increase at high speeds, and it will be difficult to meet the new standards if palladium-only catalysts are used.

Legislation and Government Programs

Mine Safety and Health Administration.—The Department of Labor's Mine Safety and Health Administration (MSHA) proposed new rules that establish health standards for underground metal and nonmetal mines that use diesel-powered equipment. Of the approximately 260 underground metal and nonmetal mines in the United States, 203 use this type of equipment. The new standards are intended to reduce risks to underground miners from health hazards associated with exposure to high concentrations of diesel particulate matter (DPM). DPM comprises tiny particles (usually less than a micrometer in size) that are emitted from diesel engines. Average concentrations of DPM observed in underground mines that use diesel equipment are up to 200 times as high as average exposures in most heavily populated urban areas. In addition, DPM levels are up to 10 times as high as median exposure estimates for workers in other occupational settings, such as inside bus repair facilities. Evidence indicates that exposure to such high concentrations of DPM puts miners at risk of incurring serious health problems, including lung cancer. The new proposal would establish a concentration limit for DPM and would require mine operators to use engineering or work practice controls to reduce DPM to the limit. An interim limit of 400 micrograms per cubic meter ($\mu g/m^3$) of air, measured as total carbon, would go into effect following an 18-month period of MSHA educational and technical assistance to mine operators. A final limit of 160 $\mu g/m^3$ of air would become effective in 5 years (Engineering & Mining Journal, 1998).

Defense National Stockpile Center to Sell Iridium.—The Defense Logistics Agency's Defense National Stockpile Center (DNSC), Ft. Belvoir, VA, has been authorized by the U.S. Congress to sell iridium in various forms beginning in fiscal year 1999. Specifically, the iridium forms that will be offered for sale are sponge—Grade A/AA/B, powder, pieces, and bar. The quantity of iridium to be sold was to be determined on or about February 15, 1999, when Congress was expected to approve the 1999 Annual Materials Plan. Sales programs were to begin in early summer. Before sales begin, DNSC will solicit input from industry and other experts on designing an appropriate and effective sales program.

Production

In 1998, Stillwater Mining Company's Stillwater Mine, near Nye, Montana, reported production of 13,810 kg of palladium and platinum, 25% higher than production of 11,042 kg in 1997. Of the 13,810 kg produced, palladium accounted for 10,575 kg and platinum accounted for 3,235 kg. The company mined 720,000 metric tons (t) of ore in 1998, 24% more than the 580,000 t mined in 1997. In conjunction with the operation of the mine, the average throughput at the mill facility was 2,200 tons per operating day with a recovery rate of 91%. The mill head grade was 21 grams per ton (g/t) of combined palladium and platinum per ton of ore in 1998, compared with 22 g/t per ton of ore in 1997. The second mill expansion, to 3,000 metric tons per day (t/d), was completed in the fourth quarter of 1998. The first expansion, upgrading the mill capacity from 1,000 to 2,000 t/d, had been completed in 1997. The 1998 mill expansion included the addition of rougher flotation cells, a tertiary grinding vertimill, a trommel screen on the semi-autogenous grinding discharge, and a cone crusher, all designed to increase throughput. To increase the grinding capacity in the mill, a surface-jaw-crusher, located on the west side of the mine, was completed in December 1998 to crush run-of-mine material.

Stillwater operated a smelter and base metal refinery (BMR) at the company's metallurgical complex in Columbus, MT. At the smelter, concentrate was treated to produce matte containing approximately 650 ounces of palladium and platinum per ton. The matte was subsequently sent to the BMR, which produced a filter cake that was 60% palladium and platinum. The filter cake was sent to metal refiners in New Jersey, California, and Germany, where it was converted into palladium and platinum sponge for sale to end users. The company also recovered small amounts of copper, gold, nickel, rhodium, and silver. The company restarted its program to process spent automotive catalysts for the recovery of PGM. In 1998, approximately 139 t was processed in the smelter at a rate of 1 t/d. The usual procedure was to blend concentrate from the mill with spent catalysts. A 32-t/d furnace, which has been operating since 1990, will be joined by a new 100-t/d furnace. Construction of the new smelter facility, adjacent to the existing facility, began in 1998. As of January 1999, 50% of the building and 75% of the engineering work had been completed (Stillwater Mining Co., 1999, p. 22). When the new facility is operational, the processing of spent automotive catalysts is expected to increase to 3 t/d. At about the same time construction of the furnace was begun, construction began on a copper-nickel refinery that will remove cobalt, copper, and nickel from the solution produced by the BMR. The copper electrowinning circuit was scheduled to be operational in the first quarter of 1999.

Proven and probable reserves for the company are contained in the J-M Reef, a 45-kilometer-long deposit in southern Montana. The average ratio of palladium to platinum contained in the reef is 3.3 to 1. At the end of 1998, proven and probable reserves contained 818,000 kg of palladium and platinum in 1.15 million kilograms of ore grading 22 g/t combined palladium and platinum.

In 1998, Stillwater hired 128 new miners. The total number of miners at the end of 1998 was 278 (Stillwater Mining Co., 1999, p. 19).

Consumption

Platinum.—In 1998, demand for platinum by U.S. automakers was flat. The reason was that PGM loadings on vehicles have, over the last few years, shifted in favor of palladium-rich catalyst. The shift accelerated in 1998 owing primarily to the introduction of the National Low Emission Vehicle (NLEV) program. The program placed particular emphasis on the control of hydrocarbon emissions. About one-third of new U.S. vehicles met these stricter standards in 1998. All vehicles manufactured after 2000 will be required to meet the stricter standards. Tighter hydrocarbon limits reinforced the current trend towards the use of palladium-based catalysts on gasoline-powered vehicles, owing to their superior performance regarding hydrocarbons. Demand for platinum in the diesel sector, however, will increase significantly as manufacturers increase platinum loadings to meet stricter emission standards for diesel-powered vehicles. In 1998, global demand for platinum grew by 6,843 kg to reach 164,850 kg, mainly owing to expansion of platinum jewelry fabrication in China and the United States (Johnson Matthey, 1999, p. 5-7).

Palladium.—Palladium will be used in all NLEV automotive catalyst systems. On some models, it will be added to existing platinum-rich systems, but on other vehicles, it will be used in place of platinum. As a result, U.S. demand for palladium will increase, further eroding the demand for platinum during the next 3 years.

World demand for palladium by the electronics industry declined by about 7% as manufacturers reduced reliance on palladium in multilayer ceramic capacitors (MLCC). In 1998, technical obstacles to the use of nickel in precision capacitors were mostly overcome with the development of new ceramic materials that are compatible with base metal electrodes. The world's largest maker of MLCC's, located in Japan, reportedly will stop using palladium in its ceramic capacitors in the near future because of the metal's high price. In the United States, lower demand for them was more than offset by the wider use of palladium in the plating of leadframes, connectors, and other electrical applications.

Higher prices contributed to lower demand for palladium in dental and jewelry alloys. Consumption in the domestic chemical industry was adversely affected by worsening economic conditions in Asia (American Metal Market, 1999).

Rhodium.—Consumption of rhodium in the United States was estimated to have increased modestly in 1998 to about 5,200 kg, stimulated by increased demand by automakers. Rhodium was added to some palladium-only catalyst systems in order to meet more rigorous emissions control standards. Autocatalyst accounted for more than 90% of demand. Rhodium's principal other application was in the manufacture of specialty chemicals. Demand from this sector was weak, as consumers drew down existing stocks to cover process losses. World consumption of rhodium for autocatalysts was estimated to have been about 15,200 kg in 1998, a decline of 280 kg compared with that of 1997. World demand for all applications was estimated to have been about 16,100 kg (Johnson Matthey, 1999, p. 40-41).

Iridium and Ruthenium.—Demand for ruthenium remained strong in 1998 as it was used in a new process that manufactured feed stock for the production of solvents and synthetic fibers. Consumption of ruthenium in the catalyst in the Kellogg advanced ammonia process was also strong in 1998. The process operated at less stringent conditions than with traditional base metal catalysts, and thus substantially reduced energy costs. Reduced sales of iridium automotive and process catalysts were somewhat offset by strong demand for crucibles for growing synthetic crystals, especially single crystal sapphires. Demand for iridium also benefitted from its increasing use in anodes for the electroplating of zinc onto steel—a process that is replacing traditional methods of coating steel parts used in the automotive industry.

Prices

For the third consecutive year, delayed shipments from Russia stimulated prices in the first half of the year. The price of platinum rose by more than $60 to reach a peak of $434 per ounce on April 14 but began to fall following news that Russian export quotas had been approved. Platinum prices declined sharply from May though October owing to the economic crisis in Asia and renewed financial and political upheaval in Russia. As a result, the price of platinum sank to a 5-year low of $337 per ounce on October 30. Platinum averaged $372.50 per ounce in 1998, compared with $396.58 in 1997.

The price of palladium increased sharply in the first 5 months of 1998 as delays of shipments from Russia caused increasing physical shortages. The price of palladium rose from a low of $201 per ounce in January to $390 in April. Prices moderated somewhat in early May but surged again in the middle of May, reaching a record high of $417 on May 18. As Russian exports resumed, prices retreated, and trading was in the $205- to $338-per ounce range for the remainder of the year. Palladium averaged $290 per ounce in 1998 compared with $184 in 1997. The price of rhodium followed a path similar to that of palladium. Shortages of Russian supplies combined with strong consumer and speculative demand caused prices to rise sharply in the first 5 months of the year. Prices rose from $380 per ounce on January 5 to $625 on February 25. Prices eased in early March, falling below $550, but rallied to more than $600 again by the end of the month. The rally continued into April and through May, reaching $675 per ounce on May 18. As more Russian material reached the market, prices stabilized from May through early December; trading was in the $574- to $650-per-ounce range. Prices rose sharply in the last weeks of December, closing out the year at a record $780 per ounce. The average price of rhodium during 1998 was $620 per ounce compared with $298 in 1997.

Strong consumer demand and supply shortages combined to push the price of iridium to $575 per ounce for a brief period in April. As the supply situation improved, prices eased to $490 in July and $430 in November, closing out the year at $410.

The price of ruthenium soared from $40 per ounce in January to $65 for a brief period in May. As availability subsequently improved, the price declined steadily to close out the year at $40.

World Review

Russia.—Russian palladium exports faced an uncertain future, as officials from the Ministry of Finance and Russia's Central Bank debated the export policy for the metal. Russian exports of palladium resumed in the last week of May after shipment delays drove prices to more than $400 per ounce and briefly above the price of platinum. Although palladium prices started to fall once exports resumed, the market remained uncertain about what Russian intentions were for the year's export volume. The metal was shipped by Almazjuvelirexport, the state trading agency, on behalf of the Finance Ministry and the producer, Norilsk Nickel. At its annual general meeting on June 19, Norilsk confirmed that production of palladium and platinum had increased by about 10% in 1977. Officials claimed that though they planned to hold nickel output down in 1998, palladium and platinum would increase by another 5% to 10%. Citing Russia's state secrets legislation, the company refused to divulge exact production. Calculations based on semiofficial data supplied by the company to Western banks in 1997 resulted in an estimate for 1998 production of 76,204 kg of palladium and 25,723 kg platinum, all of which was probably exported. The palladium and platinum appeared to have been exported without dipping too deeply into Central Bank stocks. Still unclear was the size of the Central Bank's PGM stocks, which are held separately from the Government stockpile managed by the Finance Ministry. If Norilsk Nickel's annual production was as high as the company claimed, then the Central Bank's stocks of PGM were larger than previously thought. Transfers from the Government to the bank have been going on for several years, as the Finance Ministry has sought emergency cash from the bank to fund its obligations and reduce the budget deficit. Russian press reports suggested that the Central Bank held about 300 t of palladium, which, depending on market price, could be worth between $2 billion and $4 billion. Russian press leaks reportedly hinted that the Central Bank demanded presidential authority to export 200 t in 1998. To avoid flooding the market and conserve the metal's current value, the bank reportedly negotiated for a swap, essentially to lodge the metal in a Swiss bank vault, with a nonrelease agreement. No further details on this agreement were available (Journal of Commerce, 1998).

The Krasnoyarsk nonferrous metals plant changed hands when Norilsk Nickel handed over its ownership to the Krasnoyarsk territorial government to pay off its regional tax debt. The plant, which accounted for about 95% of all PGM refined in Russia, used a 30% concentrate from the Norilsk nickel mining complex as its feed material. It supplied the privately owned Sabin Metal Corp. refinery of Chicago with precious-metals-bearing slags, refinery residues, electronic scrap, and spent catalysts through a joint venture called SAKRAS (Platt's Metals Week, 1997b). In December 1998, Krasnoyarsk and South Africa's Impala Platinum Holdings Ltd., revived a contract for shipment of precious metal concentrates from South Africa to be refined in Russia on a tolling basis and then returned as pure metal. The agreement involved the refining of iridium, rhodium, and ruthenium only. Krasnoyarsk processed concentrates from Norilsk Nickel using only 30% of plant capacity. The deal with Impala will increase that figure to 35% in 1999. Impala planned to ship more concentrates. Krasnoyarsk was Russia's leading producer of palladium and platinum ingots and powder, powdered rhodium, iridium, ruthenium, osmium, gold, technical silver, and blister platinum (Metal Bulletin, 1998a).

South Africa.—Along with byproduct cobalt, copper, gold, nickel, and silver, PGM occurred in South Africa in three separate layered reefs associated with mafic rocks of the Rustenburg Layered Suite of the Bushveld Complex in the Transvaal. They are the Merensky Reef, the UG2 Chromite Layer, and the Platreef. The PGM occurred as alloyed native metals, as platinoid minerals (e.g., sperrylite and braggite), and in copper, nickel, cobalt, and iron sulfide minerals (e.g., chalcopyrite, pentlandite, and pyrrhotite) (South Africa Department of Minerals and Energy, 1997, p. 34). Rustenburg Platinum Mines Ltd., a subsidiary of Anglo American Platinum Corp., Ltd. (Amplats), was the largest single South African PGM producer and operated three geographically separate sections, all on the western limb of the Complex. The other mines on the western limb are the two adjoining Impala Platinum Ltd. Mines, Bafokeng North Mine, and Wildebeestfontein South Mine; the two Lonrho Platinum Division mines, Eastern Platinum Ltd., and Western Platinum Ltd.; and Northam Platinum Ltd., which is controlled by Gold Fields of South Africa Ltd.

In 1998, South Africa produced about 188,000 kg of PGM, about 2% more than in 1997. Amplats was by far the largest producer. In January, the company announced a R202 million expansion project at its Amandelbult operations in the Northern Province. According to Amplats, the project will boost the mine's annual platinum output by 2,240 kg by late in 2000 and create 500 new jobs. The project will be part of a major expansion program involving other Amplats mines and a total cost of R1.8 billion. The expansion program will increase the company's annual platinum production capacity to more than 70,000 kg. The Amandelbult section produced 17,629 kg in 1998. The latest project will involve the milling of 60,000 t of UG2 ore and the enhancement of concentrator capacity and recoveries. The other expansions are taking place at Bafokeng Rasimone Mine, Potgietersrust Platinums Ltd., and Lebowa Platinum Mines Ltd.

In October, Anglo American Corp. announced a major reorganization that included moving physically and financially to London. Although much of the move will be a reordering of Anglo American's corporate structure, there were also operational changes at the company. Platinum holdings will increase through a rise in the holdings of Amplats; but a decades-long interest in U.S.-based Engelhard Corp. will come to an end. Under the reorganization, Anglo American Corp. will merge with its international arm, Minorco, take over control of several minority interests, and have a London-based listing on the London Stock Exchange (Platt's Metals Week, 1998).

Australia-based Aquarius Platinum NL forged ahead at its Kroondal platinum project in South Africa. The chromite and platinum deposit, situated in the Bushveld Complex, reportedly has a total identified mineral resource of 24.5 Mt, 5.5 g/t of predominately palladium, platinum, and rhodium. The operator of the mine, Kroondal Platinum Mines Pty. Ltd., planned to develop a 1.2-million-ton-per-year (Mt/yr) mechanized underground mine, involving stoping the Leader, Parting, and Main seams as a single unit. Studies have suggested that this mining method would have several benefits, including lower capital and operating costs, and a smaller workforce. On-site processing facilities will consist of crushing, dense-media separation, grinding, and flotation circuits to produce a high-grade PGM concentrate. The project was forecast to produce 5,400 tons per year of concentrate containing 3,110 kg of platinum, 1,550 kg of palladium, 467 kg of rhodium, and 40 kg of gold. The project was expected to produce 65.3 t of PGM during a 14-year mining life (Metal Bulletin, 1998c). Kroondal concluded an agreement with Impala Platinum to supply concentrates which Impala will smelt and refine, and also market the metals produced (Metal Bulletin, 1998b).

Zimbabwe.—In 1997 the Australian company, BHP Minerals, a division of Broken Hill Proprietary Co., Ltd., announced the first shipment of PGM from its Hartley platinum mine in Zimbabwe. The mine is a 67-33 joint venture between manager BHP Minerals and Australia's Delta Gold NL. The PGM, in the form of a gray-black powder, were shipped to England to be refined by Johnson Matthey. Full production from the mine was expected to be reached before the end of 1998. At full production, ore extraction was to total 2.16 Mt/yr, yielding 4,670 kilograms per year (kg/yr) of platinum, 3,420 kg/yr of palladium, 358 kg/yr of rhodium, and 715 kg/yr of gold (Platt's Metals Week, 1997a). The mine, however, did not reach full production in 1998.

Anglo American Zimbabwe planned to open a $70 million platinum mine at Shurugwi, central Zimbabwe, strengthening the country's chance to become the world's third largest platinum producer, after South Africa and Russia. The mine was expected to begin production in 30 months, and to produce 3,670 kg/yr of PGM and 2,500 t of nickel and copper. The new mine, Unki, would have a life span of 20 years and employ a workforce of 1,400. Anglo reported that extensive ore reserves surround the mine and that there is room to extend mine life or increase production. Anglo must secure the Zimbabwe Government's approval of a tax regime, marketing of mine output, and employment of expatriate staff. The proposed mine will be the third-largest investment in the country since independence 18 years ago. Only the Sengwa North coal-fired power station project and the Hartley Mine exceeded it in scale of investment (Financial Times, 1998).

Current Research and Technology

***Iridium-Based Superalloys Developed.*—**A study has been undertaken to evaluate the potential of iridium-based refractory superalloys for ultrahigh temperature applications. It is known that nickel-base superalloys have high strength at high temperatures because of the fcc and $L1_2$ coherent two-phase microstructure. The coherent interface between the phases prevents the movement of dislocations. Iridium, palladium, platinum, and ruthenium, have higher oxidation resistance than nickel, and higher melting points, but have microstructures similar to that of nickel. The microstructure and compression strength of Ir-15X (X = Ti, Ta, Nb, Hf, Zr, or V) were investigated at temperatures between room temperature and 1,800 °C. It was determined that the new alloys have properties equivalent to or higher than those of commercial nickel-base alloys. The goal was to develop new alloys with capabilities beyond the series of nickel-base alloys whose maximum operating temperature is approaching 1,100 °C. Greater improvement in nickel-base alloys seems unlikely because nickel's melting point is 1,400 °C. Therefore, new alloys are needed to meet the ever-increasing demand for materials with higher temperature capabilities for high-performance jet engines (Advanced Materials & Processes, 1998).

***Palladium Alloy Used to Detect Hydrogen*.—**Palladium and several alloys of palladium containing silver have applications as hydrogen-sensitive metals. As hydrogen is absorbed by palladium on a substrate, the resistance of the metal changes, and the change can be detected electronically. A limitation of this method is that as palladium dissociates and absorbs hydrogen, it undergoes a phase change, causing hysteresis. Furthermore, the phase transformation may damage the layer of palladium. Researchers at the Lewis Research Center in Ohio may have solved these problems by using a hydrogen-sensitive alloy containing palladium and titanium. The palladium-titanium alloy does not undergo a phase change in the presence of hydrogen, and the change in resistance takes place even after repeated exposure to environments containing hydrogen. The titanium also acts as trapping sites for hydrogen, thus reducing the diffusion of hydrogen through the alloy and yielding a larger change in resistance (NASA Tech Briefs, 1998).

Outlook

Demand for PGM by the automotive industry for use in catalytic converters will continue to drive the world PGM market in the next decade. Demand for palladium can be expected to increase further as manufacturers introduce catalysts with higher PGM loadings to meet stricter emissions standards in the United States and Europe. Sport utility vehicles emit three to four times as much pollution as passenger automobiles. These popular vehicles, which account for almost 50% of the U.S. market for new passenger vehicles, historically have not been required to meet low emissions requirements. New clean air standards, however, are expected to bring them into compliance within the next few years and significantly increase demand for PGM. The use of PGM in sparkplugs, especially in the United States, could also increase demand.

The outlook for increased palladium demand in electrical applications will decline in the near term. After falling sharply in 1996, demand rebounded somewhat in 1997 owing to increased production of MLCC's, which are attached to printed circuit boards by silver-palladium leads. In 1998, palladium demand was limited by continued miniaturization and selective plating. Higher prices for palladium led to the substitution of nickel in MLCC's, a trend that is likely to continue. Also, as the size of MLCC's become smaller, the older, larger types of capacitors will be replaced with surface-mounted MLCC's, which use less metal than leaded capacitors. With selective plating, only tiny specks of gold or palladium are placed on electronic contacts, thereby reducing the amounts of precious metals required.

Demand for platinum remained flat in 1998. Sales to Japan for jewelry fabrication declined but were offset by strong jewelry demand in China and the United States. Usage in automotive catalyst has stabilized, with the majority of new demand going to palladium. Long-term platinum demand will show higher growth owing to increased usage in diesel automotive catalysts.

On the supply side, new projects were under development that could add more than 24,440 kg to the annual world production of palladium. The largest will be Stillwater Mining's East Boulder underground mine in Montana. East Boulder is expected to begin production in 2001 at an annual capacity of about 15,550 kg of PGM. The other projects are located in South Africa and Zimbabwe (Strategic Report, 1999).

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[1]Prior to January 1996, published by the U.S. Bureau of Mines.

TABLE 1
U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF PLATINUM-GROUP METALS IN 1998 1/

(Kilograms)

Country	Ores and concentrates	Waste and scrap	Refined					
			Platinum	Palladium	Rhodium	Iridium	Osmium	Ruthenium
Imports:								
Australia	--	158	4,640	--	--	--	--	--
Belgium	--	43	3,440	12,200	364	--	--	--
Brazil	--	31	67	--	--	--	--	--
Canada	--	394	1,390	4,500	3	--	--	--
Chile	--	17	3	90	--	--	--	--
China	--	--	37	1,640	1	--	20	56
Colombia	--	20	163	--	--	--	--	--
France	--	505	55	353	618	40	--	7
Germany	--	279	5,670	7,750	414	371	--	535
Hong Kong	--	120	(2/)	(2/)	--	--	--	--
India	--	--	18	127	--	--	--	--
Ireland	--	5	36	556	12	--	--	--
Israel	--	72	120	--	--	--	--	--
Italy	--	82	357	1,890	7	7	--	7
Japan	--	66	908	8,230	12	--	--	--
Korea, Republic of	--	164	17	155	--	--	--	--
Mexico	--	372	49	6	2	--	--	--
Netherlands	--	--	33	--	100	--	--	--
Norway	--	71	519	1,590	34	--	--	--
Russia	--	--	9,620	93,400	3,450	458	--	772
Saudi Arabia	--	--	155	19	--	--	--	--
South Africa	--	379	54,000	24,000	6,440	528	51	6,380
Switzerland	--	2	4,580	7,160	329	11	--	271
United Kingdom	--	1,510	11,300	12,400	1,630	646	--	1,190
Other	--	1,110	57	49	21	2	--	7
Total	--	5,390	97,200 3/	176,000	13,400	2,060	71	9,230
Exports:								
Australia	--	--	3,550	92	--	(2/) 4/		
Belgium	--	1,160	13	4,260	1	--		
Bolivia	--	--	793	--	--	--		
Canada	635	118	339	1,120	(2/)	259 4/		
China	--	1	8	696	--	4 4/		
Finland	--	--	642	1	--	--		
France	--	--	286	348	(2/)	83 4/		
Germany	--	1,830	601	1,800	2	5 4/		
Hong Kong	6	--	275	60	--	(2/) 4/		
India	--	--	35	63	(2/)	1 4/		
Ireland	--	--	694	926	333	2 4/		
Israel	--	--	5	274	(2/)	-- 4/		
Italy	--	78	129	603	(2/)	(2/) 4/		
Japan	--	1,360	3,390	3,660	233	102 4/		
Korea, Republic of	--	--	557	3,340	111	1 4/		
Malaysia	--	--	53	32	--	--		
Mexico	14	4	128	3,780	(2/)	--		
Netherlands	--	--	175	1,250	--	2 4/		
Peru	--	--	323	4	--	--		
Singapore	--	--	14	30	--	45 4/		
South Africa	64	--	15	315	--	--		
Sweden	--	70	56	121	--	1 4/		
Switzerland	2	--	518	1,380	2	2 4/		
Taiwan	--	--	70	7,890	(2/)	12 4/		
United Kingdom	24	15,100	1,380	2,170	129	375 4/		
Uruguay	--	--	39	2,160	--	--		
Other	2	--	202	356	--	10 4/		
Total	747	19,700	14,300	36,700	811	904 4/		

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.
3/ Of this amount, 475 kilograms was in the form of platinum coins.
4/ Includes osmium and ruthenium.

Source: Bureau of the Census.

TABLE 2

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

(Kilograms)

Country 3/	1994	1995	1996	1997	1998 e/
Platinum:					
Australia e/ 4/	100	100	100	100	100
Canada e/ 5/	6,000	9,320	8,080	7,550	7,570
Colombia	1,084	973	669	500 e/	430
Finland e/	60	60	60	60	60
Japan 6/	691	730	816	693 r/	650
Russia e/	15,000	18,000	17,000	17,000	17,000
Serbia and Montenegro e/	10	10	10	10	10
South Africa e/ 5/	114,000	102,000 r/	105,000 r/	115,000 r/	117,000
United States e/ 7/	1,960	1,590	1,840	2,610	3,240
Zimbabwe	7	7 r/ e/	100 e/	245 r/	300
Total	139,000	133,000 r/	134,000 r/	144,000 r/	146,000
Palladium:					
Australia e/ 4/	400	400	400	400	400
Canada e/ 5/	7,000	5,950	5,160	4,810	4,810
Finland e/	100	100	100	180 r/	180
Japan 6/	1,277	2,174	2,180	1,900	1,900
Russia e/	40,000	48,000	47,000	47,000	47,000
Serbia and Montenegro e/	50 8/	50	50	50	50
South Africa e/ 5/	47,800	51,000 r/	52,600 r/	56,300 r/	57,300
United States e/ 7/	6,440	5,260	6,100	8,430 r/	10,600
Zimbabwe	17	17 r/ e/	120 e/	345 r/	400
Total	103,000	113,000 r/	114,000 r/	119,000	123,000
Other:					
Canada e/ 5/	1,970	803	697	651	650
Russia e/	3,000	3,600	3,500	3,500	3,500
South Africa e/ 5/	22,100	18,900 r/	19,400 r/	13,700 r/	13,700
Total	27,100	23,300 r/	23,600 r/	17,900 r/	17,900
Grand total	269,000	287,000	271,000 r/	281,000 r/	287,000

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through April 29, 1999. 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/ Country reports only total of PGM produced. Figures for constituent metals are estimates.

6/ Production derived entirely from imported ores.

7/ Estimates for the Stillwater Mine, Nye, MT, from published sources. A very small quantity of byproduct platinum and palladium produced from gold-copper ores was excluded.

8/ Reported figure.