Platinum-Group Metals

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In 2003, Russian nickel miner MMC Norilsk Nickel completed the purchase of a controlling interest in Columbus, MT-based Stillwater Mining Company. Stillwater operated the Stillwater Mine near Nye, MT, and the East Boulder Mine south of Big Timber, MT, and was the only U.S. producer of primary platinum-group metals (PGMs). Stillwater produced 18,200 kilograms (kg) of PGMs in 2003, 5% less than the 19,200 kg produced in 2002.

In 2003, the domestic automobile industry continued to be the major consumer of PGMs. Auto catalysts accounted for approximately 86% of rhodium consumption, 58% of palladium consumption, and 40% of platinum consumption. Despite strong vehicle sales in 2003, consumption of palladium declined as automobile manufacturers and electronic component manufacturers made concerted efforts to reduce the palladium content of their products. According to Johnson Matthey plc (2004, p. 43), purchases of rhodium by the automotive industry for use in catalytic converters increased by 6% to 19,500 kg in 2003. Much of growth in sales was owing to tightened emissions standards that necessitated an increase in rhodium loadings on auto catalysts. Also, thrifting (the reduction of the precious metal content of a product without compromising its ability to meet relevant operating standards) of palladium and platinum by automobile manufacturers was achieved by increasing the use of rhodium in some catalyst formulations. In 2003, world rhodium supplies increased by about 17% from the 2002 level owing to increased production of platinum in South Africa.

Domestic demand for ruthenium, used primarily in ruthenium-based catalysts and in the manufacture of resistors for the electronics industry, increased by 18% in 2003. Strong chemical-industry demand for ruthenium-base catalysts was responsible for much of the increase, while demand for ruthenium pastes by the electronics sector also increased. Iridium consumption increased by about 30%. The use of iridium in fabricating crucibles (used to grow high-purity crystals) for the electronics sector increased in 2003. Although demand for iridium by chloralkali manufacturers was essentially unchanged in 2003, the spread of Cativa® acetic acid technology resulted in a substantial increase in demand for iridium-base chemical catalysts.

Legislation and Government Programs

The fiscal year 2003 iridium sales program began on January 27, 2003. Under the basic ordering agreement (BOA), prospective customers were required to preregister to participate in iridium sales and to be considered for subsequent contract awards. Before customers were qualified to engage in the quoting process, they had to submit a completed BOA package to the iridium contract specialist, who evaluated the agreement package and rendered a decision in writing. The iridium 99.95% sponge listed for sale was in the form of <99.9% sponge and <99.9% powder. The material was acquired from several suppliers/producers during 1951-92. The quality of the material was taken from certificates of analysis by Government contract laboratories or original certificates from the suppliers/producers; if no certificate was available, the appropriate Defense National Stockpile Center Purchase Specification was used (Defense Logistics Agency, 2003, p. 1; Donna Black, contract specialist, Defense Logistics Agency, written commun., January 6, 2003).

Production

Stillwater reported that the Stillwater and East Boulder Mines produced 14,000 kg of palladium and 4,170 kg of platinum in 2003 (Stillwater Mining Company, 2004, p. 12). Palladium and platinum production were down 5.5% and 4.9%, respectively, compared with that of 2002. Stillwater defined mine production as the quantity of PGMs contained in a concentrate at the time it was shipped to the smelter. The company milled 662,000 metric tons (t) of ore in 2003, 18% less than that of 2002. The mill head grade was 21.3 grams per metric ton (g/t) combined palladium and platinum compared with 20.6 g/t in 2002.

Stillwater processed ore from the Stillwater Mine through a concentrator plant adjacent to the mine shaft. The mill has an approximate capacity of 2,720 metric tons per day of ore. Ore is fed into the concentrator, mixed with water and ground to a slurry to liberate the PGM-bearing sulfide minerals from the rock matrix; mill circuit recovery was 90% in 2003. Reagents are added to the slurry to separate the valuable sulfides from waste rock in a flotation circuit. In this circuit, the sulfide minerals are floated, recycled, reground, and refloated to produce a concentrate suitable for further processing. The flotation concentrate, which represents about 1.5% of the original ore weight, is filtered and transported to the company's metallurgical complex. During 2003, the Stillwater Mine produced 10,200 kg of palladium and 3,110 kg of platinum. Ore from the East Boulder Mine is transported by rail haulage to the surface, where it is treated in a similar process to ore from the Stillwater Mine. During 2003, East Boulder produced 3,800 kg of palladium and 1,060 kg of platinum (Stillwater Mining Company, 2004, p. 13, 35).

Stillwater's smelter and refinery is on property it owns in Columbus, MT. The smelter-refinery complex was scheduled to be idled for 4 to 6 weeks in the second quarter of 2004 for rebricking of the smelting furnace. Mine operations continued during the rebricking, and the concentrate produced was stored for processing following restart of the smelter. Concentrate accumulated during the rebricking was expected to be processed

by yearend 2004 (Stillwater Mining Company, 2004, p. 15).

Secondary Production of PGMs.—In 2003, recovery and recycling of autocatalysts continued to provide a growing secondary source of PGMs. The strength of the price of platinum in 2003, which averaged $694.44 per troy ounce, helped support the profitability of recovery and recycling businesses despite the fall in the price of palladium. U.S.-based collection companies sought to widen their sources for scrapped catalysts and imported increased volumes from Mexico and South America. In the United States, an estimated 13,200 kg of platinum was recovered from scrap catalytic converters in 2003, an increase of 1,380 kg from that of 2002. Despite increased attention being paid to recycling electronic scrap (a significant source of secondary palladium), the volume of palladium recovered in 2003 fell for the third consecutive year to an estimated 1,500 kg. With spending on new information technology equipment in decline, the number of obsolete products entering the recycling chain fell. The average precious-metal content of scrapped components continued to decline, reflecting the success of manufacturers in the miniaturization of components, and substitution of base metals for palladium and other precious metals.

Stillwater has been processing small spot shipments of autocatalysts from scrap catalytic converters through its metallurgical complex since 1997. A sampling facility for secondary materials is used to crush and sample the catalysts prior to being blended for smelting in the electric furnace. The discarded catalysts are obtained primarily from automobile repair shops and automobile scrap yards that disassemble old cars for the recycling of their parts. The company also processed spent petroleum refining catalysts. In 2003, the smelter processed 940 t of spent catalysts, recovering 1,440 kg of PGMs (Stillwater Mining Company, 2004, p. 15).

Increased recovery and recycling of autocatalysts was most marked in Western Europe, where improved collection and processing of scrap catalytic converters resulted in the recovery of 3,400 kg of platinum and 2,200 kg of palladium. For several years, the recycling of PGM from scrap catalytic converters in the European Union has been increasing owing to high PGMs prices and the development of legislation to increase scrap-vehicle recycling. The European end-of-life vehicle recycling directive will become effective in 2005 and aims to increase the rate of reuse and recovery of materials to 85% per vehicle by weight by 2006. Furthermore, because catalytic converters have only been required on all new gasoline cars in Europe since 1993, the proportion of automobiles fitted with catalytic converters currently being scrapped is increasing as greater numbers of these vehicles reach the end of their lives (Johnson Matthey, plc, 2004, p. 53-55).

Stillwater's proven and probable reserves are contained in the J-M Reef, a 45-kilometer-long ore body in the Beartooth Mountain Range in south central Montana. The company's proven and probable ore reserves as of December 31, 2003, reportedly totaled 36.7 million metric tons (Mt) (40.4 million short tons) with an average grade of 19.9 g/t (0.58 ounces per short ton), containing 734,000 kg (23.6 million ounces) of palladium and platinum at an in situ ratio of 3.6 to 1 (Stillwater Mining Company, 2004, p. 10).

Consumption

In 2003, global platinum sales increased by about 5% to about 203,000 kg, driven by strong demand by the Chinese jewelry market and by increased use of platinum in catalytic converters. Increased sales of diesel cars, rising light-vehicle output, tighter emissions regulations, and greater use of platinum-base catalysts at the expense of palladium combined to increase the consumption of platinum in autocatalysts by about 20% to 18,700 kg. Purchases of palladium by the domestic automotive industry were essentially unchanged in 2003 owing to the substantial use of stocks. Consumption of palladium also declined as a result of thrifting programs in the electronics sector (Johnson Matthey plc, 2004, p. 3-8).

U.S. apparent consumption of platinum was estimated to be about 141,000 kg with a net import reliance as a percentage of apparent consumption of 96%. U.S. industry consumed an additional 12,000 kg of platinum recovered from scrap catalytic converters. U.S. apparent consumption of palladium in 2003 was estimated to be 76,000 kg. Net import reliance as a percentage of apparent consumption of palladium in 2003 was estimated to be 74% (Hilliard, 2004).

Palladium.—High prices that began in 2000-01 continued to have a negative impact on U.S. demand for palladium, which declined by more than 60% to about 30,000 kg in 2003. High prices had the greatest impact on the automotive sector where manufacturers reduced their purchases of the metal through thrifting and working off large inventories. The electronics industry was also hit by high palladium prices; however, producers of multilayer ceramic capacitors were successful in replacing palladium with lower priced nickel and silver in all but the highest performance capacitors. Purchases of palladium increased in 2003 as palladium metal and manufactured components that accumulated in 2001-02 were depleted (Johnson Matthey plc, 2004, p. 8-9).

Platinum.—Diesel-powered vehicles have become increasingly popular in Europe and were estimated to have accounted for more than 30% of the market in 2003. At the same time, platinum loadings on catalysts for use with diesel engines have increased in an effort to meet European Stage III emissions requirements, which apply to all new vehicles manufactured after 2001; platinum catalysts are more efficient than palladium catalysts in reducing emissions from diesel engines. The use of platinum in diesel-catalyst formulations is expected to account for almost three-quarters of demand from the European automotive sector. The increased use of platinum in gasoline vehicles was somewhat offset by decreased demand in the electronics, glass, and jewelry industries.

Global demand for platinum in jewelry had recovered somewhat from a 4-year low in 2002 but slipped again in 2003 to 76,200 kg. Sales of platinum jewelry in China were noticeably weak in the first 6 months of 2003 owing to a combination of rising, volatile prices and the impact of the severe acute respiratory syndrome outbreak. The Japanese platinum jewelry industry continued to suffer from an uncertain economic outlook as consumers cut back on spending for luxury items. Platinum sales for jewelry fabrication in Japan dropped by 15% in 2003 to 20,700 kg, one-half the sales 4 years ago (Johnson Matthey plc, 2004, p. 3-4).

Prices

The palladium price decline that began at the end of 2001 continued almost unabated in 2003, averaging $202.999 per ounce, down 40% from its full-year 2002 average. The price declined as demand for the metal fell back to 1993-94 levels owing mostly to automobile manufacturers drawing down stocks and substitution of lower cost base metals in the electronics sector. Meanwhile, the platinum price averaged $694.44 per ounce, 28% higher than the 2002 average. Trading ranged widely, rising above $700 per ounce twice during the year before falling back on profit-taking by funds.

Palladium.—After falling sharply in mid-December 2002 to a low of $222 per ounce, the price of palladium began to rise slowly in January 2003. The average for the month was $255 per ounce. During the first 2 weeks of February, palladium continued to benefit from the rise in gold and platinum prices before starting to slide towards $240 per ounce. The average for February was $243 per ounce. The downward price trend continued in March, stalling at the mid-December 2002 low before falling to a 5-year low of $190 per ounce on March 25, $194 on March 26, and $188 on March 28.

The $150 per ounce level was breached for the first time in 6 years on April 16 when the price closed at $148 per ounce. Despite reports of Russian sales, the price ended the month above $150 per ounce, averaging $161 per ounce for the month. Palladium was trading at approximately $155 per ounce on May 19 when Johnson Matthey plc released its Platinum 2003 report emphasizing palladium's oversupplied market conditions. Surprisingly, the price increased subsequent to the release of the report, trading briefly above $180 per ounce. Upward pressure was placed on the price when General Motors Corp. was rumored to be planning to switch from the very expensive platinum to less expensive palladium to make autocatalysts. The price subsequently fixed at $198 per ounce on May 27, the highest level in 2 months. The average price of palladium in May was $166 per ounce, the first monthly average increase since January. Palladium traded in the sub-$200-per-ounce range in June before falling below $170 per ounce in mid-July.

Prices remained in the $170 to $180 range until August 21, when prices moved to the $186 to $190 per ounce range and reached a 4-month high on August 26, closing out the month at $205 per ounce. The increase in price was driven by speculative buying based on reports that there might not be enough palladium stocks to cover physical delivery obligations. Palladium averaged $181 per ounce in August, trading between $170 and $205 per ounce. The price fell below $200 per ounce in the first week of September but rallied on September 9 to a 5-month high of $232 per ounce in London, United Kingdom (CRU International Ltd., 2004a). The price increase was driven by fund buying, platinum's large premium over palladium, and speculation that automobile manufacturers were likely to switch back to palladium. Prices remained above $200 per ounce through September, averaging $211 per ounce, its highest average since March.

During October, palladium traded at slightly above $200 per ounce, averaging $201 per ounce, down by 5% from the September average. The price began to fall again in November, falling below $200 per ounce on November 26 and ending the month at $190 per ounce; the average in November was $200 per ounce. In December, palladium prices were carried higher by platinum's rise, reaching $209 per ounce on December 9 before falling back to the $190 to $200-per-ounce level for the remainder of the month. The average for December was $200 per ounce, down by 18% compared with the December 2002 average. The annual average was $203.00, down by 40% compared with the 2002 average of $339.68 (Platts Metals Week, 2004).

Platinum.—Fears of supply disruptions as the possibility of strikes at Impala Platinum Ltd. and Norilsk were revealed, a smelter accident at Lonmin's Western Platinum operations, short-term production delays at Anglo American Platinum Corporation Limited (Anglo Platinum), and a soaring gold price combined to push the January price of platinum high above the 2002 average of $542.56 per troy ounce. The price reached $630 per ounce on January 20, and 2 days later rose above $650 per ounce for the first time in 17 years. The price ended January at $669, averaging $629 per ounce and trading in a $65-per-ounce range of between $605 and $670. The price fixed at $703 per ounce on February 4, the highest since March 1980. Except for a brief period during the middle of the month when the price firmed to about $695 per ounce, the price of platinum trended lower owing mostly to profit taking. The price firmed again above $680 per ounce by the end of February, averaging $682 per ounce. Volatile trading conditions persisted into March, starting the month at $680 per ounce and increasing to a 23-year high of $711 on March 10. Owing mostly to profit taking, prices decreased to $680 per ounce on March 24 and then turned downward more sharply to $632 per ounce on March 28. The average for March was $665 per ounce and trading was in the range $630 to $711 per ounce. The price of platinum continued to fall during the last 3 days of March, falling below $620 on April 1. The price firmed in mid-month to about $640 per ounce before drifting towards $600 per ounce in the closing days of April. The average for April was $627 per ounce, the lowest monthly average since the start of the price rally in late December 2002. Johnson Matthey released its Platinum 2003 report on May 19, 2003, with a bullish outlook for platinum. The price quickly recovered to the pre-profit taking price of $620 per ounce and climbed even higher on May 27, reaching $680 per ounce before falling back to $627 per ounce on May 30. The May average was $649 per ounce, $22 per ounce higher than the April average. The price rose $20 higher in the first week of June to more than $660 per ounce on light trading volumes. The price continued to rise through the rest of June to a high of $678 per ounce on June 19, averaging $664 per ounce for the month.

Platinum prices increased in the first 2 weeks of July to levels not seen since mid-March. Some traders attributed the price increase to stepped-up buying by the automotive and jewelry sectors. Prices eventually fell back to below $679 per ounce in mid-July but increased sharply to more than $700 per ounce on July 29. The average for the month was $683 per ounce, matching the historic highs reached in February. Platinum fell back below $690 in the first week of August but moved to above $690 per ounce by mid-August. In the closing days of

August, higher prices of other precious metals, most notably gold, pushed the price of platinum to more than $700 per ounce, averaging $680 per ounce for the month. The price of platinum remained above $700 per ounce in the first 2 weeks of September, reaching $714 on September 9. Improved U.S. economic conditions and renewed speculative buying kept the price of platinum mostly above $700 per ounce for the entire month. The price averaged $705 per ounce in September, the fifth consecutive monthly increase since the April low and the highest monthly average since September 1980 (CRU International Ltd., 2004b).

Improved economic conditions in the United States and concerns about production delays at Anglo Platinum helped push October platinum prices to a 23-year high, averaging $733 per ounce, and trading between $710 and $762 per ounce. The price surge continued in November, reaching a high of more than $770 per ounce. There was some profit taking that began at the end of October that caused the price to drop by $20 per ounce to nearly $740 per ounce. However, increased physical buying by China and India and the persistent perception of a continuing market deficit caused prices to recover rapidly above $760 per ounce and then to $774 per ounce on November 13, averaging $760 for the month. The price of platinum reached $780 per ounce on December 4. On December 4, Anglo Platinum announced that, owing to the strong rand making some of its expansion projects uneconomical, it had lowered its platinum output target for 2006 (Anglo American Platinum Corporation Limited, 2003). The price fixed at $796 per ounce on the day of Anglo Platinum's announcement and moved above $800 per ounce on December 8. The high for the month occurred on December 17 at $842 per ounce averaging $810 per ounce for the month.

Other PGMs.—The price of rhodium was rather volatile during the first 5 months of 2003, trading between $440 and $650 per ounce. Having fallen sharply in December 2002 owing to yearend sales, the price of rhodium staged a recovery in January 2003, rising rapidly to $650 per ounce from $485 per ounce. After stabilizing at about $620 per ounce for most of February, the price began to slide once more as large volumes of the metal were drawn to the market from secondary and primary sources. With low demand from the automotive industry, the rhodium price fell to $440 per ounce in April, its lowest point since February 1998. During the second half of 2003, however, the price was more stable, trading close to $500 per ounce for most of the period.

During the first half of 2003, the price of ruthenium completed a 3-year decline from a peak of $170 per ounce in 2000 to a low of $30 per ounce in April 2003. The price increased to $33 per ounce in May and remained unchanged through the remainder of 2003.

The price of iridium also bottomed out during the first half of 2003 after falling sharply during 2002 owing to overcapacity in the crystal-growing sector of the electronics industry. The price fell from $125 per ounce at the beginning of January to $100 per ounce by the middle of the month. The price remained at the $100-per-ounce level through February and March before settling at almost $90 in April and $87 per ounce for the remainder of 2003.

Trade

In 2003, U.S. net import reliance as a percentage of apparent consumption was estimated to be 74% for palladium and 96% for platinum. South Africa accounted for 55% of refined platinum and 29% of refined palladium imports; Russia accounted for 35% of refined palladium imports and 10% of refined platinum imports. Total palladium imports decreased by 10% to 105,000 kg from 117,000 kg in 2002; platinum imports increased by 4% in 2003 to 88,500 kg from 84,700 kg in 2002. Rhodium imports were 12,000 kg, up from 8,630 kg in 2002. The United States exported 22,300 kg of palladium (42,700 kg in 2002), 22,200 kg of platinum (27,800 kg in 2002), and small quantities of other PGMs.

World Review

In 2003, world mine production of PGMs increased by about 9%, to 453,000 kg, compared with 414,000 kg in 2002 (table 5). South Africa, the world's leading producer of PGMs, accounted for 60% of total mine production in 2003; Russia accounted for 28%; the United States and Canada, 4% each; and Zimbabwe, 2%. South Africa, which accounted for 74% of world platinum production, increased its output of platinum by 13% in 2003 to 151,022 kg. Global output of palladium climbed to 182,000 kg, while rhodium sales were more than 16,000 kg. Russia dominated the world's mine production of palladium with 41% of the total.

China.—The Shanghai Huatong Platinum & Silver Exchange began operations on July 8, 2003. The Exchange is in the Liangyou Mansion in Pudong District. The debut of platinum metal trade on the exchange began on July 15. The spot trade of 99.95 platinum materials, the only platinum-group metal traded on the Shanghai Gold Exchange (SGE), was only allowed among the 108 members of SGE. New members registered after the spot trade of platinum was launched can only conduct business in platinum and may not buy or sell gold. China is now the world's leading consumer of platinum but produces only about 1,000 kilograms per year (kg/yr). In 2002, China imported 26,000 kg of platinum, accounting for about 14% of total world mine output. At present, most members of the exchange are from Guangdong or Hunan Provinces (Antaike Precious & Minor Metals Monthly, 2003).

Russia.—In 2003, Russia accounted for 41% of global mine production of palladium and 18% of platinum production. Despite the importance of the Russian PGMs mining industry to the world market, information on production, reserves, and sales have historically been difficult to come by, because such data were considered to be confidential under Russian state secrets law. Recently, however, Norilsk has been able to disclose some information regarding its nickel operations and made efforts to provide more details on its PGMs production, reserves, and sales. In late 2003, a bill to declassify PGMs data (with the exception of Government stocks and sales) was passed by both houses of the Russian Parliament and it was signed by the Russian President. The bill was to take effect in February 2004, but the publication of PGMs data was delayed by regulatory procedures that must be completed by several Ministries (Platts Metals Week, 2003; Mining Engineering, 2004).

In November 2002, Norilsk and Stillwater signed agreements whereby Norilsk would acquire a 51%-majority ownership in Stillwater through the issuance of 45.5 million shares of common stocks in exchange for $100 million in cash and 27,300 kg of palladium. The credit agreement had previously provided that in the event of a change in control of the company, the entire facility would immediately become due and payable. The credit agreement provided for a default in the event that the Norilsk transaction was not consummated by January 2, 2004, unless by such time the company consummated an alternate transaction that raised certain thresholds of new capital through the issuance of equity or unsecured subordinate debt. The amended agreement reportedly facilitated the company's ability to focus on lowering its operating costs (Stillwater Mining Company, 2003a). On March 20, 2003, Stillwater announced that it had received the fifth amendment to the company's credit agreement, paving the way for Norilsk to acquire a majority interest in Stillwater subject to shareholder approval, completion of a review under the Hart-Scott-Rodino Antitrust Improvements Act, and other conditions. On June 16, 2003, shareholders in Stillwater, the only primary producer of PGMs in the United States, approved the proposed transaction with Norilsk that gave Norilsk a controlling 51% shareholding in the company. On June 23, 2003, Stillwater and Norilsk closed the stock purchasing agreement. In connection with the transaction, Stillwater issued 45,463,222 new shares of its common stock to Norimet Limited (a wholly owned subsidiary of Norilsk) representing approximately 51% of Stillwater shares. In consideration for the shares, Norimet paid Stillwater $100,000,540 in cash and approximately 27,300 kg of palladium metal. Based on the price of palladium at that time, the total consideration was valued at approximately $257 million. Norilsk's ownership in Stillwater was eventually increased to approximately 56%. Stillwater is the largest primary producer of PGMs outside of South Africa (Stillwater Mining Company, 2003b).

South Africa.—The new Marikana Mine in South Africa's North West Province milled 23,000 t of ore and shipped its first PGMs concentrate (250 t), just 1 year after construction began. The mine is owned by London, United Kingdom-based Aquarius Platinum SA. Mining at Marikana is by open pit and will continue to a depth of about 100 meters, then will be followed by underground mining. Resources reportedly total 23.3 Mt grading 4.31 g/t PGMs. Concentrates from Marikana were to be treated by Impala Refining Services Ltd. (Mining Magazine, 2003).

Anglo Platinum and Aquarius Platinum SA announced that they had reached an agreement to mine adjacent properties on their respective Rustenburg and Kroondal lease areas. The agreement provided for the parties to pool their assets while retaining ownership of the properties and to share the proceeds equally. Anglo Platinum will provide access to a portion of the UG2 ore body on the Rustenburg Platinum Mines' lease area, and Aquarius Platinum will provide access to its existing Kroondal platinum mine lease area and infrastructure. The parties intend to use the existing Kroondal Mine infrastructure to gain access to the Rustenburg ore body down dip of the Kroondal Mine. Production at the Kroondal Mine reportedly will be expanded to approximately 8,700 (kg/yr) during 2006 from approximately 4,400 kg/yr of platinum. This will be achieved by using the existing Kroondal infrastructure, constructing an additional 250,000 metric-ton-per-month concentrator to be completed in 2005, and the establishing additional decline shaft capacity at Rustenburg. The venture will have minable reserves and resources of 69 Mt of ore and a mine life extending to 2016 (Anglo Platinum, 2003).

Zimbabwe.—In 2003, Zimbabwe Platinum Mines (Zimplats), which owns Zimbabwe's Hartley Complex, completed a bankable feasibility study to double its production of PGMs by the end of 2005. The plans were based on the potential development of an underground mine below its Ngezi opencast project, aimed at doubling the rate of production at Ngezi to about 12,400 kilograms per year of PGMs by 2005. The introduction of an underground component at Ngezi will increase PGMs reserves substantially to about 1.1 million kilograms (Mkg) of PGMs with a platinum-to-palladium ratio of about 1.2 to 1. Zimplats' total resources within the Hartley Complex reportedly are about 10.3 Mkg of PGMs with an average ore grade of 4.1 g/t PGMs (Platts Metals Week, 2003).

Current Research and Technology

Researchers in many countries have focused their efforts on methods of exploiting hydrogen's fuel benefits. In a proton-exchange membrane (PEM) fuel cell, hydrogen gas is consumed at temperatures below 80° C in the presence of a platinum catalyst and an oxidant (typically air) at efficiencies up to 60%. Compared with hydrocarbons, hydrogen's advantages include higher energy density and, because the sole byproduct of combustion or electrochemical oxidation of hydrogen is water, no pollution. If hydrogen is to replace current power producers, then there must be a clean, practical source of cheap hydrogen gas (H_2). One potential source is the breakdown of biomass, which requires the development of special catalysts. Researchers at the University of Wisconsin, Madison, have developed a heterogeneous catalyst that produces H_2 at temperatures near 500 K from ethylene glycol, glycerol, and sorbitol, which are all industrial byproducts. Instead of relying on expensive platinum, the new catalyst is based on cheap and plentiful aluminum, nickel, and tin (Chemical & Engineering News, 2003).

Another key obstacle to using hydrogen as a fuel for transportation and other applications is the safe storage of hydrogen. There is no convenient way for the public to store and transport large quantities of H_2. This obstacle may soon be overcome thanks to an advance in hydrogen-storage materials by a group of researchers in Japan. Japanese chemists for the first time have prepared an open-cage fullerene derivative with an orifice large enough to allow a hydrogen molecule to be inserted into the cage in 100% yield. The new molecule was prepared from buckminsterfullerene (C_{60}) in three steps in 40% overall yield. When the material was exposed to H_2 at 800 atmospheres and 200° C in an autoclave, 100% encapsulation reportedly was achieved within 8 hours. None of the encapsulated hydrogen escaped when a solution of the endohedral complex was monitored for more than 3 months at room temperature. However, H_2 was released slowly when the

solution was heated above 160 °C (American Chemical Society, 2003). Spent organic-based catalysts, which contain precious metals, have traditionally been treated by incineration to recover the precious metal content. Incineration destroys the organic content of the catalyst and leaves an ash, which is sampled to determine the precious metal content before chemical recovery is started. A new more environmentally friendly process developed by Johnson Matthey allows a spent heterogeneous catalyst, such as palladium or platinum on a carbon support, to have the metal content evaluated prior to treatment directly from the as received samples. The process has two stages; the first is to determine the precious-metal content of a catalyst using direct sampling technology. The second stage involves supercritical water oxidation, during which the carbonaceous material is converted into less noxious compounds, leaving the precious metals as their oxides (Platinum Metals Review, 2003).

Outlook

An increase in diesel car sales in Europe can be expected to cause a strong increase in use of platinum in the region in 2004 and beyond. The tightening of emissions regulations in China, Europe, Japan, and other parts of the world is also expected to lead to higher average platinum loadings on catalysts, especially on light-duty diesel vehicles, as particulate matter emissions become more closely controlled. In the United States, thrifting is continuing at most manufacturers and is likely to lead to a reduction in the use of platinum in autocatalysts. The price differential of more than $500 between platinum and palladium has led to the assumption that automobile manufacturers will change PGMs ratios on gasoline engine vehicles in favor of palladium, reversing the trend of the past 2 years.

In the long term, reaction to the State of the Union Address by the President of the United States in January 2003, could lead to a shortage of PGMs supplies to the platinum market. In a bid to reduce U.S. dependence on foreign oil, the President proposed that the Government spend $1.2 billion in research funding of hydrogen-powered vehicles. If the commitment to fund research materializes, then it could lead to the commercialization of fuel-cell technology and the development of a hydrogen economy in the United States and elsewhere in the world. As a consequence, consumption of platinum could increase substantially in the coming 10 to15 years.

Automotive industry use of palladium is expected to increase in the short term. Average loading levels on autocatalysts are expected to increase in Europe and Japan at the expense of platinum, as more stringent particulate emission standards are introduced. Now that U.S. automobile manufacturers have drawn down stocks sharply during the past year, purchases by U.S. automobile manufacturers are likely to increase. A shift towards greater use of palladium in preference to platinum on gasoline-vehicle autocatalysts by a number of manufacturers is also likely to provide a modest increase in palladium use in Europe and Asia. In Europe, however, production of gasoline automobiles is expected to decline while sales of diesel engines continue to rise, and this will somewhat offset some of the expected growth from switching to palladium. As mentioned earlier, some U.S. manufacturers may also shift PGMs ratios more in favor of palladium, but this will be substantially offset by further thrifting. In the electronics sector, component sales are expected to increase. Increased demand for palladium, however, will be somewhat offset by a combination of miniaturization and substitution of nickel and silver for palladium in multilayer ceramic capacitors. Supplies of palladium and platinum are expected to increase significantly from new mines in South Africa.

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TABLE 1
SALIENT PLATINUM-GROUP METALS STATISTICS[1]

(Kilograms, metal content, unless otherwise specified)

		1999	2000	2001	2002	2003
United States:						
Mine production:						
Palladium[2]		9,800	10,300	12,100	14,800	14,000
Value	thousands	$114,000	$228,000	$237,000	$162,000	$91,400
Platinum[2]		2,920	3,110	3,610	4,390	4,170
Value	thousands	$35,600	$54,900	$61,900	$76,500	$93,100
Refinery production:						
Palladium		10,400	7,980	9,790	5,700	6,830
Value	thousands	$122,000	$178,000	$192,000	$62,200	$44,600
Platinum		12,900	15,800	15,000	15,200	15,300
Value	thousands	$157,000	$278,000	$258,000	$265,000	$341,000
Imports for consumption, refined:						
Iridium		2,250	2,700	3,110	2,100	2,200
Osmium		23	133	77	36	53
Palladium		189,000	181,000	160,000	117,000	105,000
Platinum, includes waste, scrap, and coins		125,000	93,700	84,200	84,700 r	88,500
Rhodium		10,300	18,200	12,400	8,630	12,000
Ruthenium		11,400	20,900	8,170	9,890	15,900
Exports, refined:						
Iridium, osmium, and ruthenium, gross weight		165 r	390 r	252 r	94 r	145
Palladium		43,800	57,900	36,800	42,700	22,300
Platinum		19,400	25,000	29,300	27,800	22,200
Rhodium		114	797	982	349 r	479
Stocks, National Defense Stockpile, December 31:						
Iridium		784	784	784	784	562
Palladium		28,200	19,000	16,300	5,870	1,170
Platinum		7,060	5,190	3,680	649	649
Price, average per troy ounce:						
Iridium[3]		$411.40	$415.00	$415.25	$294.62	$93.02
Palladium[4]		$363.20	$691.84	$610.71	$339.68	$203.00
Platinum[4]		$378.94	$549.30	$533.29	$542.56	$694.44
Rhodium[4]		$904.35	$1,988.57 r	$1,598.67 r	$838.88	$530.28
Ruthenium[3]		$40.70	$129.76	$130.67	$66.33	$35.43
Employment		954	1,290	1,620	1,580	1,540
World, mine production		366,000 r	364,000 r	395,000 r	414,000 r	453,000 e

eEstimated. rRevised.

[1]Data are rounded to three significant digits, except prices.

[2]Source: Stillwater Mining Co., 2003 annual report, p. 34.

[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, BY COUNTRY[1]

Country	Grain and nuggets		Sponge		Other unwrought		Other		Waste and scrap		Coins	
	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)
2002	1,910	$34,000	72,600	$1,170,000	3,490	$53,700	4,950	$78,700	1,780 r	$61,400	20	$417
2003:												
Argentina	--	--	--	--	20	360	--	--	--	--	--	--
Australia	--	--	--	--	--	--	(2)	9	--	--	1	7
Belgium	--	--	2,910	59,700	--	--	1	19	2,220	478	--	--
Brazil	--	--	120	2,460	--	--	--	--	5	186	--	--
Canada	30	656	--	--	9	127	401	9,160	1,640	4,280	7	176
China	--	--	3	63	2	33	14	197	91	736	4	127
Colombia	2	50	--	--	382	7,550	33	657	132	2,430	--	--
Denmark	--	--	--	--	1	22	--	--	--	--	--	--
Ecuador	--	--	--	--	--	--	(2)	4	--	--	--	--
France	--	--	32	858	32	939	152	3,080	--	--	--	--
Germany	12	223	3,620	79,000	607	14,100	2,890	48,700	115	776	--	--
Hong Kong	--	--	--	--	2	43	--	--	--	--	--	--
India	--	--	22	321	--	--	1	10	--	--	--	--
Israel	--	--	--	--	721	14,500	--	--	--	--	--	--
Italy	--	--	811	18,900	--	--	522	11,000	--	--	--	--
Japan	--	--	153	3,050	995	15,000	1	18	16	657	--	--
Korea, Republic of	--	--	--	--	416	9,110	5	101	489	10,800	--	--
Mexico	--	--	--	--	--	--	1	9	63	737	--	--
Netherlands	--	--	--	--	--	--	5	56	2	32	--	--
Norway	--	--	1,080	23,300	--	--	--	--	--	--	--	--
Philippines	--	--	--	--	--	--	17	327	19	407	--	--
Russia	304	7,060	4,960	108,000	2,650	50,900	--	--	--	--	--	--
Saudi Arabia	--	--	--	--	342	7,860	--	--	--	--	--	--
South Africa	453	9,720	44,000	927,000	815	18,300	307	6,580	408	9,170	--	--
Switzerland	19	366	1,410	31,900	27	623	143	1,770	--	--	--	--
United Kingdom	30	563	10,600	228,000	177	3,480	499	7,900	41	1,060	5	117
Venezuela	--	--	--	--	2	50	4	49	2	43	--	--
Other	--	--	--	--	3	56	1	21	423	5,380	--	--
Total	849	18,600	69,700	1,480,000	7,210	143,000	4,990	89,700	5,670	37,200	16	426

[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.

Source: U.S. Census Bureau.

TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF PLATINUM-GROUP METALS, BY COUNTRY[1]

Country	Unwrought palladium		Palladium, other		Iridium[2]		Unwrought osmium		Unwrought ruthenium		Rhodium[3]	
	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)
2002	94,600	$968,000	22,000	$189,000	2,100	$20,100	36	$294	9,890	$21,400	8,630	$288,000
2003:												
Belgium	3,910	26,500	402	3,360	7	34	--	--	--	--	552	9,290
Canada	1,910	14,400	2	20	--	--	--	--	--	--	--	--
Chile	--	--	20	132	--	--	--	--	--	--	--	--
China	841	5,400	--	--	--	--	7	47	--	--	1	14
Costa Rica	--	--	--	--	--	--	--	--	--	--	2	35
Czech Republic	--	--	2	6	--	--	--	--	--	--	--	--
France	2	5	50	521	--	--	--	--	--	--	8	176
Germany	1,240	8,200	3,860	30,600	80	244	5	46	784	931	271	4,820
Italy	18	155	767	5,360	4	28	--	--	--	--	4	90
Japan	2,150	7,190	673	2,730	--	--	--	--	6	10	202	6,230
Korea, Republic of	--	--	--	--	--	--	--	--	--	--	51	1,020
Netherlands	--	--	72	896	3	22	--	--	--	--	--	--
Norway	6,090	37,400	215	1,420	--	--	--	--	--	--	62	1,030
Russia	28,900	183,000	7,200	50,300	100	193	--	--	2,260	2,240	3,600	54,300
Singapore	--	--	--	--	--	--	--	--	--	--	2	36
South Africa	27,800	169,000	2,710	16,800	1,340	3,550	40	330	12,800	13,400	6,280	108,000
Spain	6	39	--	--	--	--	--	--	--	--	--	--
Sweden	70	753	--	--	--	--	--	--	--	--	--	--
Switzerland	974	6,840	2,360	16,300	--	--	--	--	--	--	--	--
United Kingdom	9,610	58,700	2,680	16,400	665	2,010	1	7	70	129	981	16,300
Total	83,500	518,000	21,000	145,000	2,200	6,090	53	430	15,900	16,700	12,000	202,000

-- Zero.

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

[2]Unwrought and other forms of iridium.

[3]Unwrought and other forms of rhodium.

Source: U.S. Census Bureau.

TABLE 4
U.S. EXPORTS OF PLATINUM-GROUP METALS, BY COUNTRY[1]

Country	Palladium		Platinum		Platinum, waste and scrap		Iridium, osmium, ruthenium		Rhodium	
	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, gross weight)[2]	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)
2002	42,700	$350,000	27,800	$331,000	17,700	$247,000	94 r	$1,360 r	349 r	$12,500
2003:										
Argentina	1	17	6	105	--	--	--	--	4	100
Australia	253	1,590	1,290	30,900	--	--	(3)	4	1	177
Austria	--	--	7	65	--	--	--	--	1	51
Belarus	50	111	--	--	--	--	--	--	--	--
Belgium	62	377	16	326	6	230	1	4	--	--
Bermuda	--	--	(3)	3	--	--	--	--	--	--
Brazil	19	52	116	2,020	--	--	--	--	(3)	5
Canada	2,690	21,100	1,520	25,100	2,000	19,000	2	19	1	118
Chile	--	--	227	1,670	--	--	--	--	--	--
China	489	2,680	55	737	19	183	14	353	15	294
Colombia	10	30	2	20	--	--	--	--	--	--
Costa Rica	2	4	--	--	--	--	--	--	--	--
Cyprus	1	8	(3)	5	--	--	--	--	--	--
Czech Republic	3	6	18	158	--	--	--	--	--	--
Denmark	45	257	4	59	--	--	--	--	--	--
Dominican Republic	2	10	1	13	--	--	--	--	--	--
El Salvador	2	3	--	--	--	--	--	--	--	--
Finland	22	194	5	81	--	--	--	--	(3)	4
France	401	1,910	69	1,080	--	--	3	51	(3)	42
Germany	4,810	19,200	4,790	85,600	1,020	9,510	24	147	55	999
Haiti	55	164	--	--	--	--	--	--	--	--
Hong Kong	570	2,140	224	2,930	1	22	28	675	262	5,100
India	20	49	14	249	--	--	--	--	1	123
Ireland	38	158	851	14,400	--	--	--	--	12	1,630
Israel	77	605	4	65	--	--	--	--	--	--
Italy	84	531	47	648	--	--	--	--	9	159
Japan	1,510	10,500	3,810	65,500	817	18,400	--	--	78	1,760
Korea, Republic of	84	406	236	3,970	2	18	--	--	--	--
Liechtenstein	13	122	10	182	--	--	--	--	--	--
Malaysia	8	30	41	674	--	--	--	--	--	--
Mexico	75	240	47	750	--	--	--	--	2	383
Netherlands	1,160	4,610	54	741	--	--	--	--	--	--
New Zealand	91	604	11	85	--	--	--	--	--	--
Norway	68	644	30	348	--	--	--	--	--	--
Peru	--	--	1	11	--	--	--	--	--	--
Philippines	8	43	28	321	--	--	--	--	--	--
Saudi Arabia	6	31	2	19	--	--	--	--	--	--

See footnotes at end of table.

TABLE 4--Continued
U.S. EXPORTS OF PLATINUM-GROUP METALS, BY COUNTRY[1]

Country	Palladium		Platinum		Platinum, waste and scrap		Iridium, osmium, ruthenium		Rhodium	
	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)	Quantity (kilograms, gross weight)[2]	Value (thousands)	Quantity (kilograms, metal content)	Value (thousands)
2003--Continued:										
Singapore	141	348	39	612	--	--	13	67	2	266
Slovakia	14	52	--	--	--	--	--	--	--	--
Slovenia	23	61	--	--	--	--	--	--	--	--
South Africa	--	--	368	6,960	--	--	--	--	(3)	21
Spain	108	735	7	100	--	--	--	--	--	--
Sweden	44	269	42	490	--	--	--	--	--	--
Switzerland	2,180	14,800	1,580	32,000	3,210	60,900	--	--	--	--
Taiwan	3,030	10,600	229	2,760	--	--	--	--	1	84
Thailand	89	442	33	433	--	--	--	--	1	99
Turkey	3	22	3	36	1	8	1	7	--	--
United Arab Emirates	3	27	--	--	--	--	--	--	(3)	20
United Kingdom	3,880	14,600	6,350	62,800	16,600	269,000	60	777	36	3,630
Other	35	179	19	265	(3)	3	--	--	(3)	12
Total	22,300	110,000	22,200	345,000	23,700	377,000	145	2,110	479	15,100

[r]Revised. -- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Unit of measure changed from kilograms metal content to kilograms gross weight on December 8, 2004.
[3]Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 5
PLATINUM-GROUP METALS: WORLD PRODUCTION, BY COUNTRY[1, 2]

(Kilograms)

Country[3]	1999	2000	2001	2002	2003[e]
Platinum:					
Australia[4]	90	171	174	200 [e]	225
Canada	5,663	6,302	7,410	7,400 [e]	7,400
Colombia	448	339	674	661 [r]	700
Finland	500	441	510	508 [r]	500
Japan[5]	737	782	791 [r]	762 [r]	750
Poland[6, 7]	21	21	20 [e]	20 [e]	20
Russia[e]	32,000	34,000 [r]	35,000 [r]	35,000	36,000
Serbia and Montenegro[e]	5	5	5	5	5
South Africa	121,304	114,459	130,307	133,796	151,022 [8]
United States[9]	2,920	3,110	3,610	4,390	4,170 [8]
Zimbabwe	479	505	519	2,306 [r]	4,400
Total	164,000	160,000 [r]	179,000 [r]	185,000 [r]	205,000
Palladium:					
Australia[4]	816	812	828	810 [r]	820
Canada	8,939	9,949	11,700	11,500 [e]	11,500
Finland[e]	150	--	--	--	--
Japan[5]	5,354	4,712	4,805 [r]	5,618 [r]	5,600
Poland[6, 7]	12	12	12 [e]	12 [e]	12
Russia[e]	67,000 [r]	71,000 [r]	72,000 [r]	73,000 [r]	74,000
Serbia and Montenegro[e]	25	25	25	25	20
South Africa	58,164	55,818	62,601	64,244	72,758 [8]
United States[9]	9,800	10,300	12,100	14,800	14,000 [8]
Zimbabwe	342	366	371	1,943 [r]	3,170
Total	151,000 [r]	153,000 [r]	164,000 [r]	172,000 [r]	182,000
Other platinum-group metals:					
Canada[e]	716	720	720	700	700
Russia[e]	13,400 [r]	14,100	14,500	14,500	14,600
South Africa	37,011	36,493	35,839	41,721	49,594 [8]
Zimbabwe	37	40	42	480 [r]	760
Total	51,200 [r]	51,400	51,100	57,400 [r]	65,700
Grand total	366,000 [r]	364,000 [r]	395,000 [r]	414,000 [r]	453,000

[e]Estimated. [r]Revised. -- Zero.

[1]World totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Table includes data available through April 29, 2004. 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]Based on official Polish estimates.

[7]Estimates based on reported platinum and palladium-bearing final (residual) slimes and then average Pt and Pd content from electrolytic copper refining.

[8]Reported figure.

[9]A very small quantity of byproduct platinum and palladium produced from gold-copper ores was excluded.