

# PLATINUM-GROUP METALS

By Robert G. Reese

Six metals—platinum, palladium, rhodium, iridium, ruthenium, and osmium—make up the platinum-group metals (PGM). Their unique combination of chemical inertness, refractoriness, and catalytic activity bring them many uses. PGM's are used as catalysts in the automotive, chemical, and petroleum-refining industries. They are also used in the electrical and electronic, dental and medical, and jewelry industries. Of the six metals, platinum and palladium are the most important commercially.

Although the metals of the group generally are found together, mineable deposits of the PGM are very rare. Often, PGM production occurs as a byproduct of the mining of some other metal, usually nickel or copper. The major PGM-mining countries are, in order of importance, South Africa, Russia, Canada, the United States, and Colombia.

Identified world PGM resources at yearend 1995 were estimated at 100 million kilograms. The reserve base was estimated at 66 million kilograms and reserves at 56 million kilograms. Of the reserve base and the reserves, South Africa had nearly 90% of each; Russia had 9% and 11%, respectively; and the United States had 1% and 0.4%, respectively.

In the United States, the Stillwater Mine, in Montana, accounts for nearly all domestic primary PGM production. Stillwater smelts the ore locally; the resulting PGM-bearing matte is shipped to Belgium for refining. Production at Stillwater consists primarily of palladium and platinum. Production of recoverable metal declined for the second consecutive year in 1995 despite record ore production. In 1994, the mine produced 1,960 kilograms of platinum and 6,440 kilograms of palladium; while in 1995, the mine produced 1,590 kilograms and nearly 5,260 kilograms of platinum and palladium, respectively.<sup>1</sup> Company officials attributed the lower production to operating difficulties during the middle of the year. During the second and third quarters, the company processed subgrade material produced from the development of new stopes to replace high grade stopes depleted in early 1995.

Progress continued on the company's plan to increase ore production at Stillwater from 336,000 metric tons per year to more than 660,000 tons per year by mid 1997. Among the accomplishments in 1995 were the sinking of a 530-meter shaft adjacent to the concentrator, expansion of concentrator capacity, and replacement of the mine's mobile fleet.

The remaining domestic primary PGM production is a byproduct of the refining of primary copper; it is recovered from anode slimes at two copper refineries in Texas and Utah.

Secondary PGM derived from scrap materials were refined by about 20 firms, mostly on the East and West coasts. Other

companies throughout the United States collected scrap materials such as catalysts and PGM-bearing solutions and processed them to increase the grade. These upgraded secondary materials were then sold to refiners. Most companies specialize in refining or upgrading a particular type of scrap. Because of their high value, PGM are routinely recovered from petroleum catalysts, chemical catalysts, automobile catalysts, glass fiber bushings, electronic scrap, laboratory equipment, dental materials, and jewelry.

PGM were sold by at least 90 processors and retailers, largely in the Northeast. Johnson Matthey in their annual review of the PGM estimated that the North American demand for platinum was 30,000 kilograms, for palladium 60,000 kilograms, and for rhodium 7,000 kilograms. It is believed that most of this material was consumed in the United States.<sup>2</sup>

The primary domestic use for PGM was in automotive applications. Automobiles and light trucks used platinum, palladium, and rhodium in catalytic converters to reduce their emissions. Other automotive applications include oxygen sensors, and certain types of spark plugs, both of which used small quantities of platinum.

The nonautomotive applications of PGM were numerous. The petroleum-refining industry used PGM, principally platinum, in reforming, cracking, and isomerization reactions. Other inorganic PGM catalyst applications include the syntheses of nitric acid and hydrogen cyanide using platinum and rhodium, and the production of hydrogen peroxide using palladium. PGM catalysts were also used to produce a variety of organic chemicals.

Electronic applications for PGM include the production of thick film resistors using ruthenium, the production of thick film conductors using palladium, and the use of platinum "targets" for sputtering thin films on circuit boards. Platinum-rhodium alloys were used in thermocouples for precise temperature measurement.

For glass applications, platinum, rhodium, and palladium were used in bushings for the extrusion of textile (continuous filament) glass fiber.

The Engelhard average price for unfabricated platinum increased from \$406.24 per ounce for 1994 to \$425.32 per ounce for 1995. Similarly, the Engelhard average price for palladium increased from \$144.13 for 1994 to \$153.46 for 1995. For 1995, the Engelhard average price for iridium was \$74.14; for rhodium, \$464.66; and for ruthenium, \$26.72. In 1994, the average prices were \$80.00, \$763.90, and \$20.70 per ounce for iridium, rhodium, and ruthenium, respectively.

Platinum stocks held by the New York Mercantile Exchange (NYMEX) decreased to 2,376 kilograms at yearend 1995 from 7,720 kilograms at yearend 1994. Palladium

stocks held by NYMEX increased from 991 kilograms at yearend 1994 to 1,075 kilograms at yearend 1995. Stocks of PGM's held by the Federal Government in the National Defense Stockpile remained unchanged from 1994, and at yearend 1995 consisted of 14,100 kilograms of platinum, 39,300 kilograms of palladium, and 920 kilograms of iridium.

The United States remained dependent on imports of PGM. For the period 1992-95, the U.S. imported more than 240,000 kilograms of platinum. Of this amount, South Africa supplied more than 60% of U.S. imports, the United Kingdom 10%, and Russia 7%. During the same period, the United States imported more than 356,000 kilograms of palladium. The major source countries were Russia, 36%; South Africa, 25%; and the United Kingdom, 12%. All unwrought and semimanufactured PGM can be imported duty free.

Although platinum, palladium, and rhodium are so efficient in automotive catalysts that they have no competitive substitutes, the percentage of each metal used in the catalysts can be varied. Silver and gold are alternatives for platinum and palladium in many end uses including electrical and electronic applications, jewelry, and dental applications.

### **Outlook**

Given the widespread demand for a cleaner environment, worldwide demand for PGM is expected to grow moderately over the next few years. Many countries already require the use of catalytic converters for controlling emissions from gasoline-powered automobiles, and other countries are expected to adopt these requirements. Although both platinum and palladium are used in catalytic converters, in the

short term, platinum is expected to remain the dominant metal, owing primarily to the need to use up to three times as much palladium to obtain the desired emissions reduction. Domestically, moderate growth for PGM demand is also expected over the next few years as increasingly stringent standards for automobile emissions are adopted.

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<sup>1</sup>Stillwater Mining Co. 1995 Annual Report, 56 pp.

<sup>2</sup>Cowley, A. Platinum 1996. Publ. by Johnson Matthey PLC, London, England. 52 pp.77

### **OTHER SOURCES OF INFORMATION**

#### **U.S. Geological Survey Publications**

Page, Norman J., Clark, Allen L., Desborough, George A., and Parker, Raymond L., 1973, Platinum-group metals, in Brobst, D.A., and Pratt, W.P., United States mineral resources: U.S. Geological Survey Professional Paper 820, p. 537-545.

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Platinum-Group Metals. Ch. in Mineral Commodity Summaries, annual.

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#### **U.S. Bureau of Mines Publications**

Platinum-Group Metals. Ch. in Minerals Yearbook, annual.

TABLE 1  
U.S. IMPORTS FOR CONSUMPTION AND EXPORTS OF PLATINUM GROUP METALS IN 1995 1/

(Kilograms)

Country	Ores and concentrates	Waste and scrap	Refined					
			Platinum	Palladium	Rhodium	Iridium	Osmium	Ruthenium
<b>Imports:</b>								
Australia	--	67	2	--	--	--	--	--
Belgium	--	--	1,150	7,940	152	--	--	--
Brazil	--	2	--	105	--	--	--	--
Canada	--	203	255	2,730	1	--	--	--
Chile	116	--	--	--	--	--	--	--
China	--	--	1,040	2,550	11	--	--	20
Colombia	--	--	982	--	--	--	--	--
Finland	--	81	--	--	--	--	--	--
France	--	384	--	297	164	9	--	--
Germany	--	175	3,570	4,560	371	252	4	349
Hong Kong	--	364	--	--	30	--	--	--
India	--	--	--	41	--	--	--	295
Ireland	--	214	2	3	--	--	--	--
Italy	--	14	664	410	49	--	--	--
Japan	--	5	334	6,210	--	--	--	--
Mexico	7	133	23	11	4	--	--	--
Netherlands	--	637	73	544	74	--	--	--
Norway	--	--	489	3,010	15	--	--	--
Russia	--	140	8,110	56,200	1,930	93	--	290
South Africa	--	187	43,900	22,400	6,120	893	69	6,200
Switzerland	--	--	4,070	2,750	281	95	--	238
Taiwan	--	150	--	369	--	--	--	--
United Kingdom	--	3,530	6,590	13,700	405	108	--	130
Other	--	64	190	55	--	--	--	--
<b>Total</b>	<b>120</b>	<b>6,350</b>	<b>71,500</b>	<b>124,000</b>	<b>9,600</b>	<b>1,450</b>	<b>73</b>	<b>7,520</b>
<b>Exports:</b>								
Australia	--	--	94	65	--	2 3/		
Belgium	--	552	2,010	4,280	--	--		
Brazil	--	--	4	2	--	--		
Canada	--	159	694	1,000	--	5 3/		
China	7	58	1	--	--	1 3/		
Denmark	--	--	14	45	--	--		
Finland	--	--	191	--	--	--		
France	--	--	401	214	--	3 3/		
Germany	149	1,910	1,130	1,300	26	4 3/		
Greece	--	--	--	28	--	--		
Hong Kong	--	--	30	28	--	4 3/		
Ireland	--	--	1,180	619	166	--		
Israel	--	--	52	284	--	--		
Italy	--	35	149	322	--	--		
Japan	3	282	3,790	5,750	352	36 3/		
Korea, Republic of	7	--	2,850	343	170	--		
Malaysia	--	--	12	--	--	--		
Mexico	--	1	113	3,290	2	--		
Netherlands	--	--	285	837	4	--		
New Zealand	--	--	--	33	1	--		
Norway	--	--	6	27	--	--		
Russia	--	1,750	--	--	--	--		
Singapore	--	1	8	1,020	--	--		
South Africa	113	1	1	1	--	--		
Spain	--	--	1	46	--	--		
Sweden	--	251	13	575	--	--		
Switzerland	282	39	637	1,230	--	--		
Taiwan	--	--	77	2,900	--	1 3/		
Turkey	--	1	8	--	--	--		
United Kingdom	15	3,080	1,170	1,650	19	12 3/		
Other	22	28	31	115	1	16 3/		
<b>Total</b>	<b>600</b>	<b>8,150</b>	<b>15,000</b>	<b>26,000</b>	<b>741</b>	<b>84 3/</b>		

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Of this amount, 1,070 kilograms was in the form of platinum coins.

3/ Includes osmium and ruthenium.

Source: Bureau of the Census.

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

(Kilograms)

Country 3/	1991	1992	1993	1994	1995 e/
<b>Platinum:</b>					
Australia e/ 4/	100	100	100	100	100
Canada e/ 5/	4,680	4,800	5,000	6,000	6,040
Colombia	1,600	1,960	1,720	1,080 r/	1,100
Ethiopia e/	1	1	-- r/	-- r/	--
Finland e/	60	60	60	60	60
Japan 6/	988	629	661	691 r/	580
Russia e/ 7/	XX	28,000	20,000	15,000	18,000
Serbia and Montenegro 8/	XX	19	10 r/	10 r/ e/	10
South Africa e/ 5/	88,900	94,900	109,000	114,000 r/	118,000
U.S.S.R. e/ 7/ 9/	30,000	XX	XX	XX	XX
United States e/ 10/	1,500 r/	1,600 r/	2,100 r/	2,000	1,600
Yugoslavia 8/ 11/	22	XX	XX	XX	XX
Zimbabwe	19	9	4	7 r/	10
<b>Total</b>	<b>128,000</b>	<b>132,000</b>	<b>139,000 r/</b>	<b>139,000 r/</b>	<b>145,000</b>
<b>Palladium:</b>					
Australia e/ 4/	400	400	400	400	400
Canada e/ 5/	6,440	5,800	6,000	7,000	7,100
Finland e/	100	100	100	100	100
Japan 6/	1,050	986	1,180	1,280 r/	2,000
Russia e/ 7/	XX	70,000	50,000	40,000	48,000
Serbia and Montenegro 8/	XX	130	72 r/	50 r/	50
South Africa e/ 5/	38,000	41,000	48,000	47,800 r/	49,400
U.S.S.R. e/ 7/ 9/	82,000	XX	XX	XX	XX
United States e/ 10/	5,200 r/	5,400 r/	6,800 r/	6,400	5,300
Yugoslavia 8/ 11/	155	XX	XX	XX	XX
Zimbabwe	30	19	11	17 r/	20
<b>Total</b>	<b>133,000 r/</b>	<b>124,000 r/</b>	<b>113,000 r/</b>	<b>103,000 r/</b>	<b>112,000</b>
<b>Other Platinum-group Metals:</b>					
Canada e/ 5/	586	1,310	1,440	1,970	1,960
Russia e/ 7/	XX	6,000	4,000	3,000	3,600
South Africa e/ 5/	16,000	17,000	19,000	22,100 r/	22,800
U.S.S.R. e/ 7/ 9/	9,500	XX	XX	XX	XX
<b>Total</b>	<b>26,100</b>	<b>24,300</b>	<b>24,400</b>	<b>27,100 r/</b>	<b>28,400</b>
<b>Grand total</b>	<b>287,000 r/</b>	<b>280,000 r/</b>	<b>276,000 r/</b>	<b>269,000 r/</b>	<b>286,000</b>

e/ Estimated. r/ Revised. XX Not applicable.

1/ Data are rounded to three significant digits; may not add to totals shown.

2/ Table includes data available through May 30, 1996. Platinum-group metal 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, Papua New Guinea, and the Philippines are believed to produce platinum-group metals, 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. However, a part of this output not specifically reported by country is presumably included in this table credited to Japan.

4/ Platinum-group metals recovered from nickel ore processed domestically. Platinum-group metals extracted from exported ores are believed to be included in the production figures for Japan, and may be included in figures for other receiving countries.

5/ Country reports only total of platinum-group metals produced. Figures for constituent metals are estimates.

6/ Production derived entirely from imported ores.

7/ All production in the U.S.S.R. for 1991 came from Russia.

8/ All production in Yugoslavia for 1991 came from Serbia and Montenegro.

9/ Dissolved in Dec. 1991.

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

11/ Dissolved in Apr. 1992.