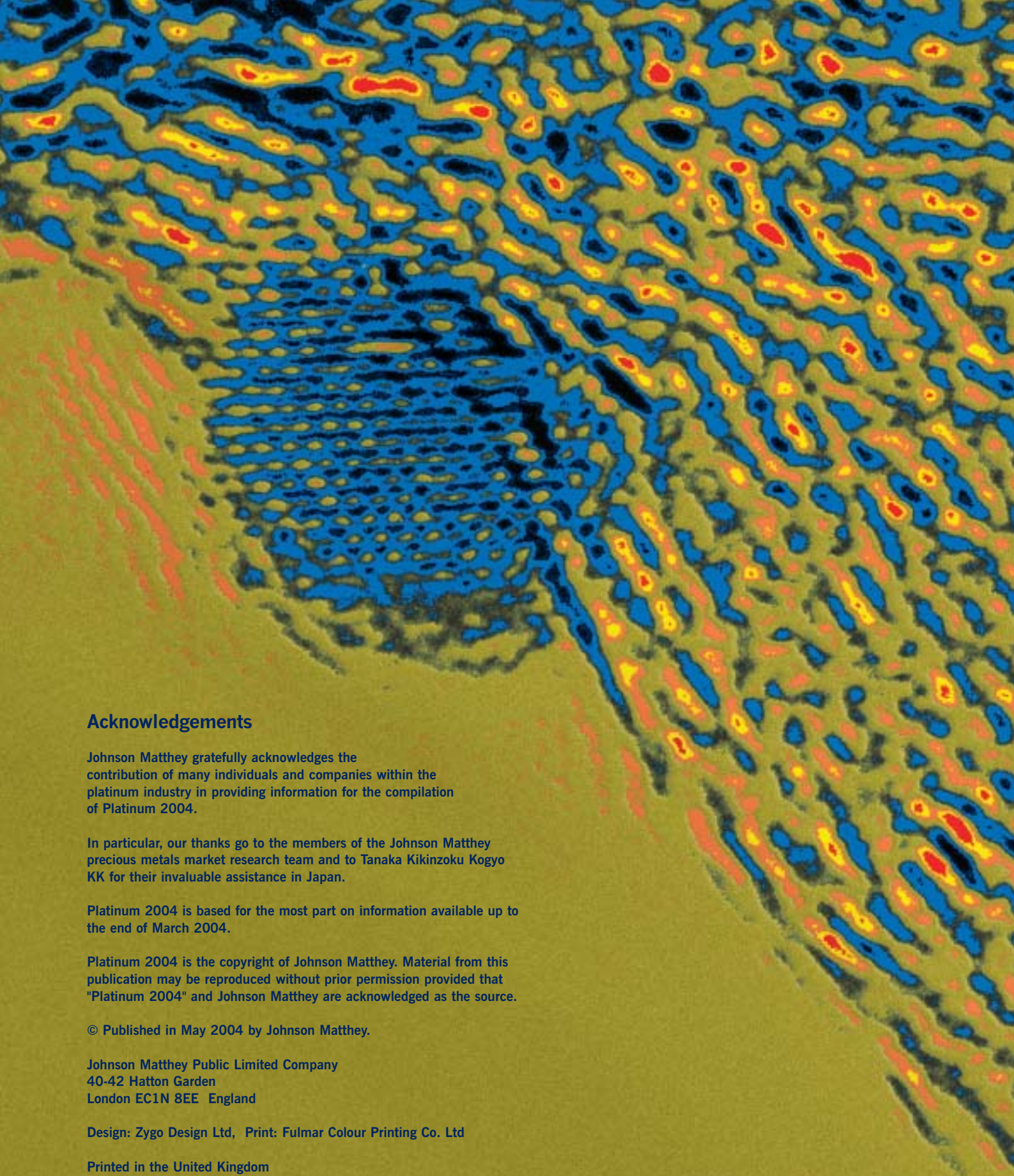
Platinum 2004

Johnson Matthey



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The front cover photograph shows a section through an autocatalyst. Catalytic converters first entered mass production in 1974 and a special feature to mark the 30th anniversary of their commercial use appears in this issue.

The photograph on this page is an image of a platinum nanoparticle within a fuel cell catalyst. The particle is approximately 3 nanometres (3 millionths of a millimetre) in diameter.

Platinum 2004

by Tom Kendall

Special Reports

Supply and Demand Tables

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Johnson Matthey

Supplies of platinum climbed faster than demand in 2003, reducing the market deficit to 280,000 oz.

Purchases of platinum for jewellery manufacture fell by 13 per cent in 2003, primarily as a result of the rapidly rising price of the metal.

Summary and Outlook

Platinum

- **Demand** for platinum in 2003 increased by just under 1 per cent to 6.52 million oz. Autocatalyst purchases of platinum climbed but demand from the jewellery sector fell.
- Purchases of platinum for use in **autocatalysts** surged by 600,000 oz to 3.19 million oz. US auto companies returned to the market for almost all their metal requirements, having run down stocks in 2002, whilst diesel car sales in Europe grew rapidly.
- **Jewellery** demand for platinum dropped by 380,000 oz to 2.44 million oz. The rising platinum price cut profit margins for Chinese jewellery fabricators and affected retail sales in Japan.
- **Industrial** demand for platinum weakened to 1.52 million oz. Use of the metal in hard disks increased but glass manufacturers reduced their holdings of metal and less new capacity was added in Asia.
- **Supplies** of platinum grew by 4.5 per cent to 6.24 million oz. South African output expanded steadily and Russian sales increased, but North American production dropped.
- The platinum market remained in deficit for the fifth year in succession. Funds built up substantial long positions and the **price** climbed by 40 per cent to a peak of $842 in December, the highest fixing since March 1980.

Demand for platinum in 2003 edged up by 50,000 oz to 6.52 million oz. Purchases of metal by the autocatalyst industry increased robustly but demand from the jewellery market dropped, primarily as a consequence of the sharp rise in the price of platinum. Supplies of platinum expanded more rapidly than demand, rising by 270,000 oz to 6.24 million oz. The market, therefore, remained in deficit for the fifth year in succession but the gap between supply and demand narrowed.

Purchases of platinum for use in **autocatalysts** jumped by 23 per cent to 3.19 million oz in 2003. In North America, auto makers bought substantially more metal than the year before, when inventories of platinum were used to supplement purchases. European demand climbed to a record high on the back of further growth in diesel car sales, and Japanese autocatalyst demand for platinum was boosted by new heavy-duty diesel emissions regulations in Tokyo. The burgeoning Chinese car market provided additional demand in the Rest of the World region, whilst tightening emissions standards worldwide also helped to support platinum use.

Demand for platinum from the global **jewellery** industry dropped by 13 per cent in 2003 to 2.44 million oz as both Chinese and Japanese manufacturers cut back their purchases of the metal. In China, the fast climbing spot price of platinum meant that profit margins throughout the sector were squeezed; whilst in Japan there was a significant increase in the volume of metal recycled from stocks. In both markets, the higher platinum price enhanced the competitiveness of white gold jewellery.

Total **industrial** demand for platinum softened to 1.52 million oz. Electrical demand rose as orders for electronic goods containing hard disks rebounded from the downturn the year before, and shipments of high temperature thermocouples to the steel industry increased. Offsetting this, however, was a drop in purchases of platinum-clad equipment by the glass industry as manufacturers stepped up efforts to minimise their holdings of metal and as fewer new glass furnaces came on stream in Asia.

Net demand for physical platinum **investment** products slumped to just 15,000 oz. The rising price of the metal stimulated sales of greater volumes of coins and bars back to the market and affected new purchases by investors.

Supplies of platinum grew by 270,000 oz to 6.24 million oz in 2003. The expanding pgm mines in South Africa and Zimbabwe delivered higher platinum output, while shipments from Russia rose as primary production was supplemented by sales from stocks. These increases outweighed a drop in North American platinum sales.

The platinum **price** performed remarkably in 2003, appreciating by more than 35 per cent from the opening fixing of the year of $600 to the final fixing of $814. Although platinum supply continued to lag behind physical demand, the strength of the price owed much to purchasing of platinum futures by funds through the NYMEX and TOCOM exchanges.

The speculative buying of platinum was part of a substantial flow of fund money into commodities as a whole in 2003, related to the weakening US dollar and rising global industrial output. In addition, the appreciation of the rand meant cash flows and profit margins for South African pgm producers were reduced, raising market expectations that expansions to supply would be deferred. These were confirmed in December when Anglo Platinum scaled back its expansion programme, reducing its target production for 2006 by 500,000 oz to 2.9 million oz.

Platinum Supply and Demand
'000 oz

	2002	2003
Supply		
South Africa	4,450	4,670
Russia	980	1,050
North America	390	295
Others	150	225
Total Supply	**5,970**	**6,240**
Demand		
Autocatalyst: gross	2,590	3,190
recovery	(565)	(645)
Jewellery	2,820	2,440
Industrial	1,545	1,520
Investment	80	15
Total Demand	**6,470**	**6,520**
Movements in Stocks	**(500)**	**(280)**

Impala suspended mining at the Crocodile River operation in South Africa in 2003 due to very difficult geological conditions underground.

Supply

Supplies of platinum from **South Africa** increased by 5 per cent to 4.67 million oz in 2003, a new record high. The total, however, was not as great as it might have been as several mine and process plant expansions slipped behind schedule.

Anglo Platinum produced 2.3 million oz of refined platinum in 2003, an increase of just over 2 per cent on the previous year but 100,000 oz below the initial plan. Output at the group's expanding Waterval mine jumped higher but did not hit target, whilst adverse geological conditions at the Modikwa joint venture slowed development of the mine. Refined platinum output at Anglo Platinum was also affected by the simultaneous commissioning of a new smelter at Polokwane, and a new converting process and slag cleaning furnace at Rustenburg, which caused a higher than planned temporary build-up in pipeline stocks of metal.

A combination of the appreciation of the rand, falling palladium and rhodium prices, and rising local costs caused Anglo Platinum to re-evaluate its long-term expansion programme in 2003. In December the group announced that it would reduce the pace of development at several projects, including the planned new mines on the eastern limb of the Bushveld Complex. As a result, Anglo Platinum now expects to produce a total of 2.9 million oz of refined platinum in 2006 compared with the previous target of 3.4 million oz.

Production from Impala Platinum's core lease area remained broadly stable in 2003 at a little over 1 million oz of refined platinum. At the Crocodile River mine, however, in which Impala holds an 83 per cent interest, output suffered due to very difficult geological conditions underground. In November, Impala halted mining at the site and in March 2004 reported that it had reached an agreement in principle to sell its entire interest in the operation to the Salene Platinum Consortium. During 2003 Impala also announced its intention to divest its 27 per cent shareholding in Eastern Platinum and Western Platinum, the operating subsidiaries of Lonmin, but the deal had not been finalised by late April 2004.

Platinum output from Lonmin's operations increased by 21 per cent last year to 916,000 oz. This was achieved despite the company's new smelter being out of action for repair for almost the entire year. The volume of ore mined jumped due to the open cast exploitation of shallow reserves of UG2 ore, and average grades and recoveries also increased.

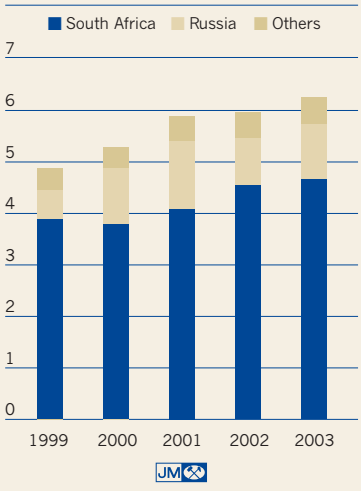
Northam Platinum successfully increased pgm output in 2003 as the volume of ore rose and head grades improved. Production of pgm attributable to Aquarius Platinum jumped by more than a third as mine production at all of its operations increased, and output at SouthernEra's developing Messina project also climbed.

Supplies of platinum from **Russia** increased by 7 per cent to 1.05 million oz in 2003 as mine production was supplemented by sales of metal from stocks. The sales of metal from inventories are believed to have been made primarily, if not entirely, by the state treasury, Gokhran, rather than by the Central Bank. A decree to repeal the secrecy laws concerning pgm production data was signed by President Putin in November, but it now appears that further procedures have to be completed before details of geological reserves and mine production can be released.

North American supplies of platinum dropped by almost 25 per cent in 2003 to 295,000 oz – due almost entirely to a slump in pgm output at Inco. The fall was partly predicted (the depletion of a pgm-rich ore zone at one of the company's mines) and partly unexpected (a three month strike during the summer). In contrast, **Zimbabwean** platinum production accelerated to 140,000 oz in 2003, an increase of almost 50 per cent, as expansions of the Ngezi and Mimosa operations bore fruit.

Supply of Platinum 1999-2003

Million oz



Demand

The **autocatalyst** industry purchased a record total of 3.19 million oz of platinum in 2003, up by 23 per cent compared with the year before. In North America, purchases of platinum by auto manufacturers jumped to 880,000 oz, a year-on-year increase of 310,000 oz. Much of the surge in buying was because US auto makers had substantially depleted their inventories of platinum during 2002, and so had to purchase almost all of their metal requirements in the market last year.

Purchases of platinum by the European auto industry climbed by 11 per cent in 2003 to 1.34 million oz, propelled by rising demand for platinum-based autocatalysts for diesel cars. Sales of diesel cars in Europe rose by over 5 per cent to exceed 6 million

units for the first time as their market share grew to more than 43 per cent. In addition, average platinum loadings per car increased as manufacturers introduced models that meet tighter emissions limits that will be imposed under Euro IV regulations.

The introduction of new heavy-duty diesel emissions legislation in the Tokyo metropolitan area was largely responsible for an 19 per cent increase in Japanese autocatalyst demand for platinum in 2003, the total rising to 510,000 oz. Trucks and buses operating in Tokyo and surrounding areas that did not meet the tough NOx and particulate matter emissions limits were required to be retrofitted with diesel oxidation catalysts or catalysed particulate filters.

Platinum demand for autocatalyst manufacture in the Rest of the World accelerated by 21 per cent to 460,000 oz, driven by a phenomenal rise in new car production and sales in China. Output of Chinese manufactured cars leapt to just over 2 million units, up from 1.21 million in 2002, whilst new car sales soared by 72 per cent, also to over 2 million vehicles. Car sales in India also increased rapidly in 2003, nearing the 700,000 mark, whilst emissions regulations in both countries continued to tighten.

Global demand for platinum from the **jewellery** industry fell by 380,000 oz in 2003 to 2.44 million oz as manufacturers in both China and Japan purchased significantly less metal than the year before.

Purchases of platinum for jewellery manufacture in China dropped by 19 per cent to 1.2 million oz, the first fall since the market started to develop in the mid-1990s. Profit margins on platinum jewellery in China dropped throughout the year as the spot price of the metal increased faster than rising retail prices.

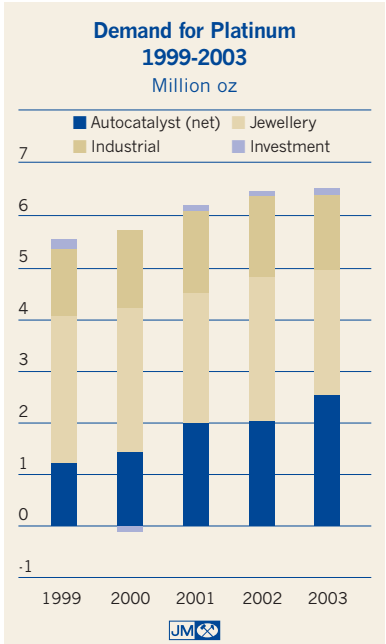
As a result, platinum stock levels were reduced throughout the industry, manufacturers deferred purchases of metal, many increased their output of higher margin white gold jewellery, and some suspended production of platinum jewellery altogether. A combination of higher prices for platinum jewellery, fewer new platinum designs coming to the market, plus increased choice and promotion of white gold items resulted in retail sales of platinum jewellery falling by an estimated 10 per cent in 2003.

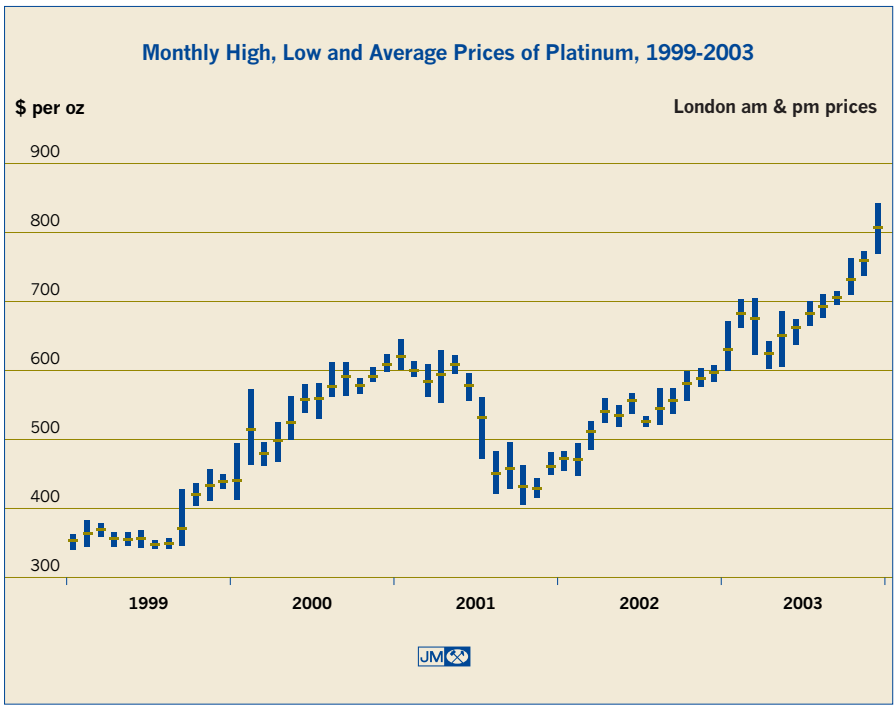
On a more positive note, the advent of trading of platinum on the Shanghai Gold Exchange in August enabled manufacturers to source metal more easily and made pricing more transparent. By the end of the year more than 246,000 oz of platinum had been bought via the exchange.

In Japan, purchases of platinum for jewellery manufacture slid by 15 per cent to 665,000 oz, around half the level of demand of four years ago. Although platinum jewellery maintained its overall market share, the Japanese jewellery market as a whole contracted. In addition, purchases of platinum by manufacturers fell due to a further rise in the volume of stock recycled, with the liquidation of inventories from bankrupt companies contributing a significant amount of metal to the market.

North American purchases of platinum for jewellery were stable in 2003 at 310,000 oz. Increased penetration of white gold jewellery at the lower priced end of the market was offset by increased platinum sales in higher price brackets of both the fashion and bridal sectors. Growth in the UK platinum jewellery market was the highlight in Europe, sales of platinum jewellery remaining subdued in Germany and Italy. Overall, platinum demand for jewellery manufacture in the region increased by 6 per cent to 170,000 oz.

Total **industrial** demand for platinum slipped marginally lower in 2003 to 1.52 million oz; purchases of metal for electrical applications climbed but





From August 2003 onwards, Chinese users of platinum were able to purchase physical metal, effectively free of VAT, via the Shanghai Gold Exchange.

demand for platinum from the glass and chemical industries fell.

A strong recovery in sales of computers and other electronic goods led to a rebound in shipments of hard disks in 2003, following two years of depressed demand. This fed through to a rise in purchases of platinum, a key component of the magnetic alloys used in hard disk manufacture. Demand for platinum wire used in high temperature thermocouples also increased as production of both steel and semiconductors rose.

In the glass industry, the growth in manufacturing capacity for LCD glass continued in Asia but the rate of new plant construction fell. In addition, the high price of the metal led many glass companies to minimise their inventories of platinum equipment and to defer purchases of new products. The emphasis on reducing the amount of platinum held throughout the glass industry led to an increase in the volume of metal sold back to platinum refiners and fabricators.

After two years of very good orders for platinum-based catalysts, demand from the bulk chemicals industry slipped in 2003. Less new paraxylene manufacturing capacity was planned and suppliers of catalysts to the silicones industry had some success in thrifting the percentage of platinum used per catalyst. Demand for platinum in other applications rose modestly: orders for catalysts from the petroleum refining industry and consumption of platinum in biomedical applications and turbine blades increased, but the market for platinum-gold dental alloys fell (a reaction to the higher prices of both metals).

Outlook

The gap between platinum demand and supply narrowed in 2003 and the market is set to move close to equilibrium in 2004 – it could even be in the position of a small surplus. A substantial increase in supplies is forecast, whereas growth in total demand is projected to be slight as increased purchases by the auto industry are likely to be offset to a large extent by weaker jewellery demand.

Chinese jewellery demand may well fall for the second year in succession in 2004. This will largely depend on how jewellery manufacturers and retailers respond to movements in the price of platinum over the course of the year and whether they can earn attractive profit margins.

Although good volumes of metal were sold to jewellery manufacturers during the first few days of January, ahead of the Chinese New Year holiday, demand subsequently weakened when the price of the metal surged. Reports from China suggested that some jewellery manufacturers were continuing to migrate an increasing proportion of output to white gold, whilst a handful began to experiment with the production of palladium jewellery. However, when the price of platinum fell sharply in late April, Chinese purchases of platinum jumped (*see chart*).

Little change is projected for platinum purchases by jewellery manufacturers in other regions in 2004. The Japanese market is forecast to stabilise, after three years of very weak demand, as improving economic growth feeds through to greater consumer confidence. In Europe and North America, platinum jewellery is likely to face further pressure in lower price brackets from white gold but this could be offset by higher sales in the bridal sector.

Purchases of platinum by the global automotive industry are forecast to climb to another record high in 2004, regardless of moves by some car manufacturers to switch more heavily in favour of palladium in gasoline autocatalysts. The increase in platinum demand will again be propelled by yet higher sales of diesel cars in Europe as they gain further market share from gasoline vehicles.

In addition to higher diesel car sales, the strict limits on particulate matter emissions set under the Euro IV regulations will necessitate the introduction of catalysed diesel particulate filters (DPF) on an increasing number of larger, heavier diesel car models. In addition, although a majority of smaller diesel cars will be able to meet Euro IV limits without the use of catalysed DPF, they are becoming increasingly popular optional extras.

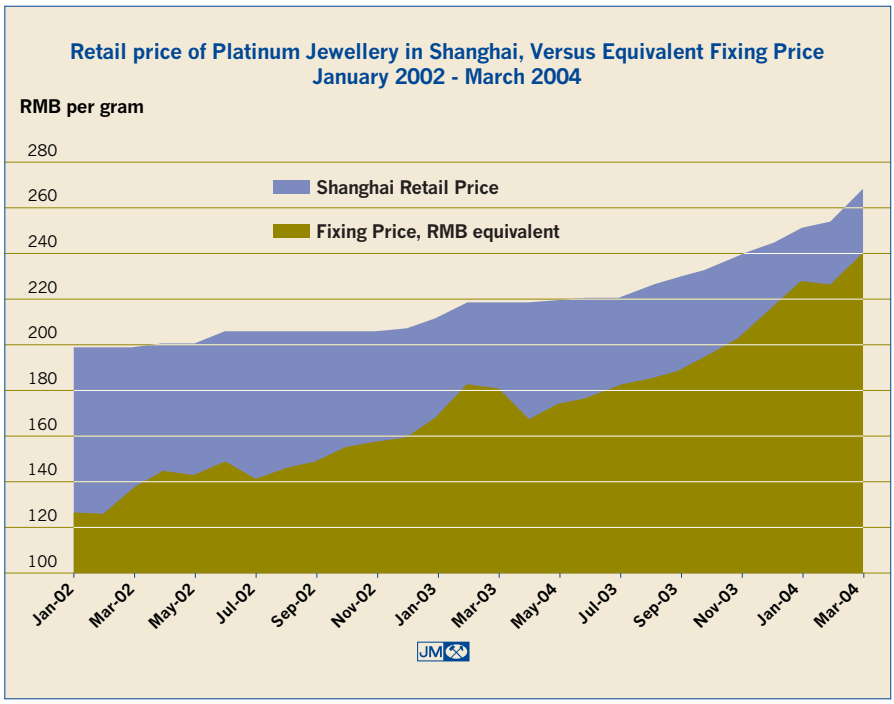
As in 2003, purchases of platinum by the US auto industry this year will closely reflect the underlying level of consumption of the metal in autocatalysts. This is expected to fall slightly as palladium-based catalysts replace platinum-based formulations on some vehicles, a reaction to the large premium that has developed between the price of platinum and that of palladium. The impact on metal demand is likely to be more pronounced in 2005 as catalyst changes take effect on an increasing proportion of new models.

Following the one-off rise in Japanese autocatalyst purchases of platinum in 2003 due to the Tokyo heavy-duty diesel legislation, demand is forecast to edge lower in 2004. The effect of this, however, should be outweighed by greater use of the metal in China and India as light vehicle production continues to expand rapidly. South Korean car output is also expected to show good growth this year, after having been largely static in 2003.

Demand for platinum in industrial applications is forecast to improve, supported by rising shipments of hard disks in the electrical sector. Glass industry demand is expected to increase, with most manufacturers having reduced their metal holdings as far as possible in 2003, and consumption of platinum in catalysts for the chemicals industry is also likely to trend upwards.

Total supplies of platinum are projected to rise significantly faster than demand this year. South African output is likely to exceed 5 million oz for the first time as more metal flows from expansion projects at most of the existing producers. Output from the Zimbabwean pgm mines will also continue to grow, and North American shipments are expected to recover from last year's fall.

During the first quarter of 2004, the platinum price continued to be driven upwards, with much of the momentum coming from fund buying of futures. The price climbed rapidly from an opening fixing of $815 on the 2nd of January to almost $870 in mid-month before dipping back towards $820 by early February as Chinese buying fell away. The rally then resumed as funds reacted to a substantial weakening of the US dollar and appreciation of the South African rand by increasing their long positions in platinum. By the middle of March the price had passed $900 and it peaked with a fixing of $937 on the 19th April.



From the 20th of April onwards, however, funds suddenly turned net sellers of precious and base metals as the US Federal Reserve hinted that US interest rates were likely to rise in the relatively near future and the dollar subsequently strengthened. As an initial burst of long liquidation pushed the price downwards, additional sell orders were triggered. The rush to close out positions accelerated and by the afternoon fixing on the 29th of April the platinum price had plunged to $783.

In conclusion, the platinum market is projected to be closer to balance in 2004, and supplies may even exceed demand for the first time since 1998. To what extent this easing of the fundamentals affects the price of the metal will mainly depend on whether the late-April fund sell-off in platinum proves to be a temporary phenomenon or the start of a more permanent readjustment of speculative portfolios. Our forecast price range for platinum for the next six months is $780 to $920, the large spread reflecting the potential for further volatility in the market.

Palladium

- **Demand** for palladium recovered by 9 per cent in 2003 to 5.26 million oz but this was still the third lowest total for a decade.
- Purchases of palladium for use in **autocatalysts** jumped by 410,000 oz to 3.46 million oz as US car companies used far less metal from inventories. Thrifting, however, reduced the underlying consumption of the metal.
- The **electronics** industry purchased 895,000 oz of palladium, an increase of 18 per cent versus 2002 when use of stocks depressed demand.
- The use of palladium in **dental** alloys dropped by 8 per cent to 725,000 oz in 2003. In Japan, the largest market, demand slumped when the state subsidy for dental treatment was cut.
- **Supplies** of palladium rebounded by 23 per cent to 6.45 million oz in 2003. Unlike the previous year, Russian production was fully sold and South African output expanded.
- With supplies rising faster than demand, the palladium market surplus widened to 1.19 million oz. The palladium **price** consequently weakened, ending the year at $193, some $41 below the opening fixing in January despite growing fund investment.

Palladium Supply and Demand
'000 oz

	2002	2003
Supply		
South Africa	2,160	2,310
Russia	1,930	2,950
North America	990	940
Others	170	250
Total Supply	**5,250**	**6,450**
Demand		
Autocatalyst: gross	3,050	3,460
recovery	(370)	(410)
Dental	785	725
Electronics	760	895
Other	605	590
Total Demand	**4,830**	**5,260**
Movements in Stocks	**420**	**1,190**

Global demand for palladium increased by 430,000 oz in 2003 to 5.26 million oz, primarily as a result of a sharp rise in purchases by US auto makers, who used far less metal from stocks than the year before. Purchases of metal by electronic component manufacturers also increased following depletion of inventories in 2002. In both industries, however, the underlying use of the metal fell due to thrifting.

Supplies of palladium surged by 1.2 million oz in 2003 to reach 6.45 million oz, closer to the level of global mine production than at any time over the past decade. As ever, Russian shipments of palladium were a major influence – Norilsk Nickel sold all of its production in 2003 after having held back a substantial proportion of its output the previous year.

The increase in supplies of palladium outweighed the improvement in demand, leading to a surplus of 1.19 million oz – this coming on top of substantial surpluses in the previous two years. Consequently, the palladium price was under pressure for much of 2003, despite the fact that buying of futures by funds accelerated during the second half of the year. Palladium ended the year at $193, 17.5 per cent below the opening fixing of $234 in January.

Purchases of palladium by the **autocatalyst** industry recovered by 13 per cent in 2003, rising to 3.46 million oz. This was not due to an increase in consumption of the metal in autocatalyst manufacture; on the contrary, use of the metal fell for the third year in succession as thrifting continued in all regions. However, because US car companies used far less palladium from inventories than they had in 2002, they purchased substantially more metal in the market in 2003.

Purchases of palladium for the manufacture of **electronic** components, the second largest market for the metal in 2003, also increased, jumping by 135,000 oz to 895,000 oz. Again, the rise was largely because manufacturers had run down excess inventories during 2002 (both of palladium pastes and finished components), and so bought substantially more metal in 2003. As in the auto industry, however, the underlying use of palladium decreased year-on-year. The average palladium content of conductive pastes was further reduced and the miniaturisation of components continued.

Demand for palladium in **dental** alloys dropped to 725,000 oz in 2003, a fall of 60,000 oz. Although the decline in the price of palladium stimulated modest improvements in demand in the European and North American markets, purchases of metal by the Japanese dental sector slumped as a result of a cut in the government subsidy for dental treatment.

Demand for palladium in **other** applications weakened by 2.5 per cent to 590,000 oz as purchases of the metal for use in both jewellery alloys and chemical catalysts edged downwards.

Supplies of palladium surged to 6.45 million oz in 2003, an increase of 1.2 million oz from the previous year. Shipments of palladium from Russia jumped by more than 50 per cent to 2.95 million oz as sales of metal by Norilsk Nickel closely reflected mine output, the company having withheld a substantial volume of its production from the market in 2002. Supplies of palladium from South Africa and Zimbabwe also climbed, rising in line with expanding platinum output and outweighing a fall in North American production.

The palladium **price** staged a brief rally from $234 to just over $270 during the first few weeks of 2003, as industrial demand picked up following a typical year-end lull in December 2002. However, from early February through to mid-April the price weakened, sliding to a six year low of $144.

Strong fund buying of palladium futures in August and September then produced a second rally, which reached $232, but large offers of physical metal and a lack of interest from industrial purchasers had driven

the palladium price back under $200 by the end of the year. The price softened despite the fact that funds continued to open substantial long futures positions.

By the end of 2003, hedge funds and other investment funds had built up a total net long futures position equivalent to over 500,000 oz of palladium on NYMEX, and were estimated to have accumulated a similar sized net long position on TOCOM. On top of this, derivatives contracts equivalent to an estimated 1.5 million oz or more of palladium are believed to have been arranged through over-the-counter deals.

The speculative investment in palladium was part of a wider boom in the commodities markets as a whole but ran counter to the supply and demand fundamentals of the metal. Funds were partly attracted to palladium due the conviction that the widening premium between it and the price of platinum would become unsustainable, which would encourage auto companies to increasingly favour the use of palladium in gasoline autocatalysts. In addition, there was an awareness that US auto industry stocks were likely to be depleted during 2003. In short, having sunk to a low point of under $150, the palladium price was seen as having considerably more upside potential than downside risk.

Supply

Russian sales of palladium jumped by 53 per cent to 2.95 million oz in 2003. In contrast to the previous year, when it withheld a significant proportion of its production, Norilsk Nickel sold its entire output in 2003. The majority of the metal was shipped under contracts with end users, with the remainder being sold via the spot market. Some palladium, estimated to be less than 10 per cent of total Russian supplies, is also believed to have been sold from central government stocks last year.

Norilsk's deal to acquire a majority shareholding in Stillwater Mining Co. was finalised in June. The 877,169 oz of palladium that were used as part payment for its Stillwater holding were exported from Russia to London before the end of March 2003 but as the metal was not sold to end users during 2003 it does not appear in our supply figures for the year.

A bill to amend the Russian state secrecy legislation covering data on pgm reserves, production and sales (excluding those made by the state) was passed by both houses of the Russian parliament in October last year and was signed by President Putin in November. The bill then came into effect in February 2004 but it now appears that further procedural hurdles must be overcome before data on pgm production can be published.

Supplies of palladium from **South Africa** grew by 7 per cent to 2.31 million oz in 2003 as pgm mining and processing expansions gathered pace. The rate of increase in refined palladium output was slightly higher than that of platinum as UG2 ore (which generally has a higher palladium content than the Merensky Reef) accounted for a greater percentage of the total volume of ore mined. Sales of palladium from the two pgm mines in **Zimbabwe** also climbed, in proportion to rising platinum output.

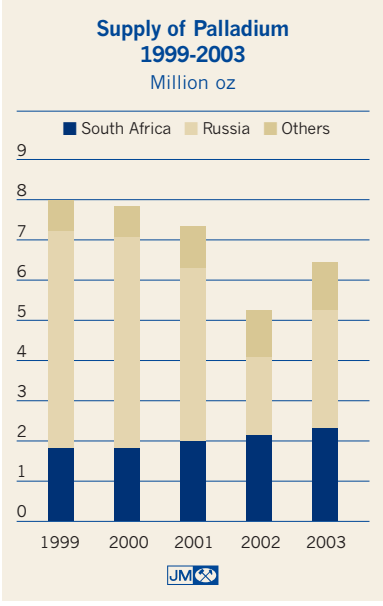
Palladium production in **North America** slipped by 50,000 oz to 940,000 oz in 2003. Output from Inco dropped sharply (in line with the fall in the company's platinum production), and reduced mining rates at the Stillwater mine led to a decrease in Stillwater Mining's refined palladium output. These negative factors, however, were largely offset by a jump in palladium output at North American Palladium following the successful commissioning of a new primary crusher.

Demand

Purchases of palladium by the **autocatalyst** industry last year recovered from the slump of 2002, rising by 13 per cent to 3.46 million oz, an increase of 410,000 oz.

The improvement in purchases of palladium was due almost entirely to a marked upturn in buying by the US auto industry. In 2002, US auto companies consumed well over 1 million oz of palladium from inventories, and a significant volume of metal was also sold back to the market. Although some US auto makers continued to run down their remaining stocks of palladium in 2003, they sourced a much greater proportion of their metal requirements from the market, with buying increasing during the second half of the year. Consequently, North American purchases of palladium for autocatalysts almost doubled from 640,000 oz in 2002 to 1.21 million oz in 2003.

In sharp contrast to the rise in the volume of metal purchased, the amount of palladium consumed in the manufacture of autocatalysts dropped for the third year in succession as a number of leading car companies continued to thrift catalyst loadings. This was particularly true in North America, where use of the



metal fell by more than 20 per cent.

In Europe, an 11 per cent drop in gasoline car production in 2003 had a knock-on effect on palladium demand; purchases of the metal in the region fell by 160,000 oz to 1.21 million oz.

Japanese purchases of palladium increased by 4 per cent to 540,000 oz in 2003 but the improvement was due to the fact that use of stocks had depressed purchases in 2002, albeit on a much smaller scale than in the USA.

With palladium trading at a substantial and widening discount to platinum in 2003, some car companies took steps to reduce their platinum consumption by electing to switch to palladium-based catalysts on new gasoline vehicle models. These decisions, however, came too late to have any significant impact on palladium demand in 2003.

Consumption of palladium in the **electronics** industry in 2003 continued to be adversely affected by thrifting, as well as by the ongoing miniaturisation of components. Despite a sharp upturn in sales of multi-layer ceramic capacitors (MLCC – the largest electronics application for palladium) and an increase in palladium-based MLCC manufacturing capacity in Asia, use of the metal dropped by 7 per cent overall.

Nevertheless, purchases of palladium jumped by 18 per cent year-on-year to 895,000 oz. As in the auto industry, electronic component manufacturers ran down excess inventories in 2002 (in this case, of palladium pastes and finished components), depressing purchases of palladium. With stocks having returned to normal levels by 2003, demand for the metal rebounded.

Demand for palladium for use in **dental** alloys dropped by 60,000 oz to 725,000 oz in 2003, a fall of 8 per cent. The reduction in overall demand was a result of a slump in Japan, by far the largest market for palladium-based dental alloys. A proportion of the cost of the 20 per cent palladium alloy used in dentistry in Japan is reimbursed under a state-run programme. However, in April 2003, the percentage of the cost payable by patients was increased from 20 to 30 per cent (having risen from 10 to 20 per cent just four years earlier). This had an immediate negative impact on the number of visits for dental treatment made by the Japanese public. Palladium demand in Japan for the year as a whole consequently fell by 20 per cent to 405,000 oz, the lowest level for more than a decade.

The slide in the Japanese market greatly outweighed modest improvements in demand in North America and Europe, where the fall in the price of palladium and rise in the price of gold made dental alloys based on the former more competitive.

Purchases of palladium for **industrial** and other markets edged down by 15,000 oz to 590,000 oz in 2003. A fall in the use of palladium-based catalysts by the bulk chemicals industry outweighed a slight increase in demand for palladium catchment gauze by nitric acid producers. Purchases of palladium for use in jewellery alloys slipped in 2003 due to the contraction of the Japanese platinum jewellery market, where the most common platinum alloys contain between 5 and 15 per cent palladium. In addition, Chinese jewellery manufacturers used less palladium in white gold alloys, preferring less expensive metals such as nickel, silver, tin and zinc.

Outlook

The first three and a half months of 2004 were marked by further heavy buying of palladium futures by funds via the New York and Tokyo futures exchanges and through over-the-counter deals. With offers of physical metal easing from the high levels seen at the end of 2003, the speculative buying finally had a conspicuous impact on the price of palladium, which climbed from $194 at the beginning of January 2004 to hit a peak of $333 on the 13th of April.

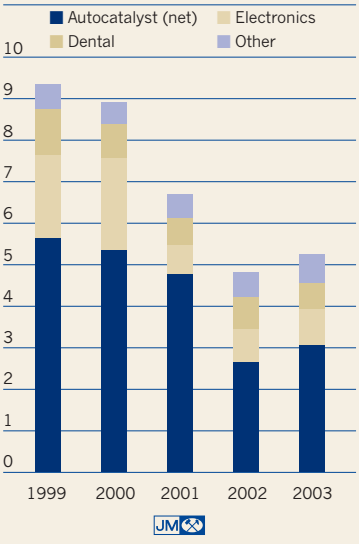
Trading sentiment towards the metal was boosted by an announcement by a European autocatalyst company in early April that it had developed a diesel car catalyst containing a proportion of palladium in place of platinum. (Because of the particular operating environment of diesel exhausts, diesel oxidation catalysts have to date contained only platinum).

However, between the 20th and 22nd of April, the palladium price plunged, hit by the long liquidation of fund futures positions that was seen across both the base and precious metals markets. The price dropped from a morning fixing of $321 on the 20th to an afternoon fixing of $257 on the 22nd of April, a fall of 20 per cent in three days. The price of palladium subsequently recovered somewhat on the 23rd, moving up to trade between $270 and $280.

Despite the burst of long liquidation, hedge funds and other investors still held very substantial long

Demand for Palladium 1999-2003

Million oz



positions in palladium towards the end of April 2004. The perception remained that, although the spread between platinum and palladium had narrowed (closing from $613 on the morning of the 20th to $549 on the afternoon of the 26th), it was still unsustainably large and that the possible upside in palladium was greater than the downside in platinum.

We forecast a further increase in auto industry purchases of palladium for use on gasoline vehicle autocatalysts in 2004, as stocks within the US auto industry were largely depleted during 2003. In addition, switching to greater use of palladium-based autocatalysts for gasoline vehicles will begin to have a greater impact. Nevertheless, thrifting will continue to affect consumption of the metal in autocatalysts in most major markets in 2004.

Demand for palladium in dental alloys should also improve this year as the number of dental treatments performed in the Japanese market starts slowly to recover. In addition, North American demand for palladium-based dental alloys is likely to rise moderately for the third year in succession if the price of palladium remains significantly below that of gold.

Purchases of palladium for use in electronic applications are projected to weaken slightly in 2004, despite further growth forecast for component sales. Thrifting, miniaturisation and the rising recovery of palladium from electronic scrap (particularly in Europe where new legislation will come into effect in 2005) are expected to depress purchases of the metal.

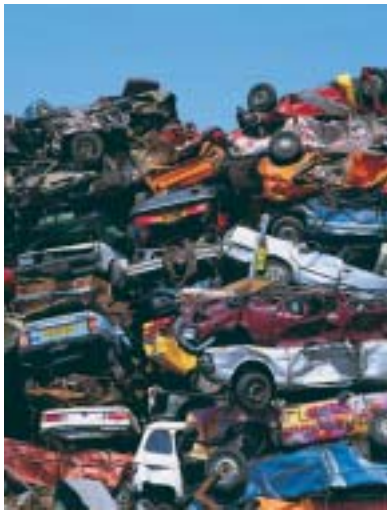
The contraction of profit margins on platinum jewellery in China to very low levels during the final quarter of 2003 and first quarter of 2004 led a number of manufacturers to start producing palladium jewellery. With much less competition than in the platinum jewellery sector, participants were able to price in much higher profit margins.

We estimate that in excess of 250,000 oz of palladium were purchased by Chinese jewellery manufacturers during the first three months of 2004 as stocks of palladium jewellery were built up. However, by late April manufacturers and retailers were reported to be disappointed with the initial level of sales, with suggestions that palladium jewellery has not been well received by the public.

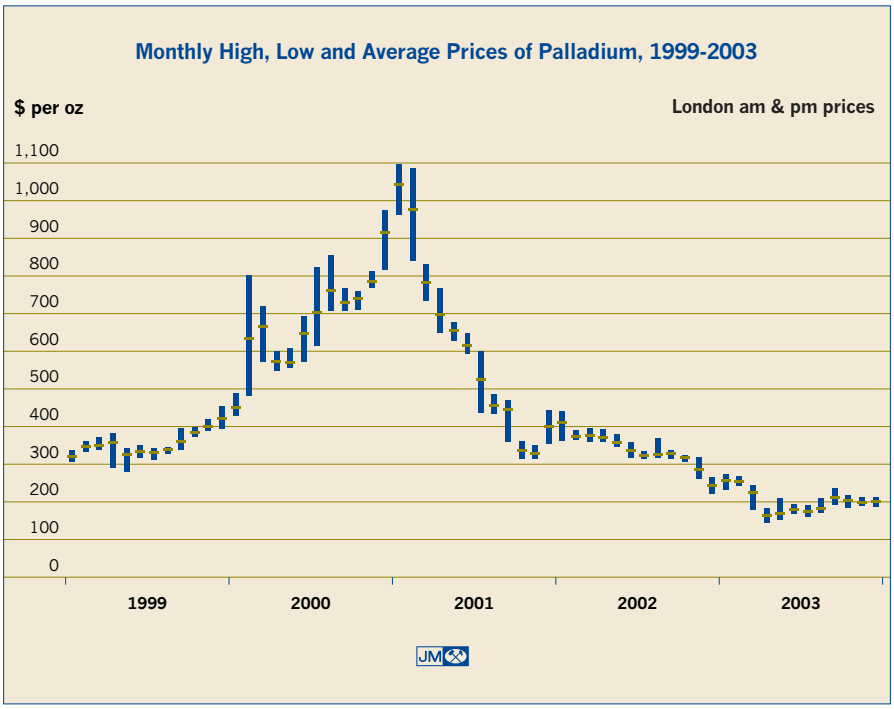
In summary, we believe that palladium demand has the potential to rise faster in 2004 than it did in 2003, driven by a higher level of purchasing by the US auto industry as the impact of stock use finally dissipates. Demand for palladium-based dental alloys should also improve, and an upturn in the use of palladium catalysts by the chemicals industry is likely.

At the same time, supplies of palladium are expected to rise substantially in 2004: South African mine and plant expansions will deliver significantly more metal this year; in the region of 400,000 oz of palladium is expected to be supplied under contract to the autocatalyst market from the stocks held by Stillwater Mining; and recovery of palladium from autocatalysts is projected to climb rapidly as heavily palladium-loaded catalysts that were fitted to vehicles in the mid-1990s are recycled in increasing volumes.

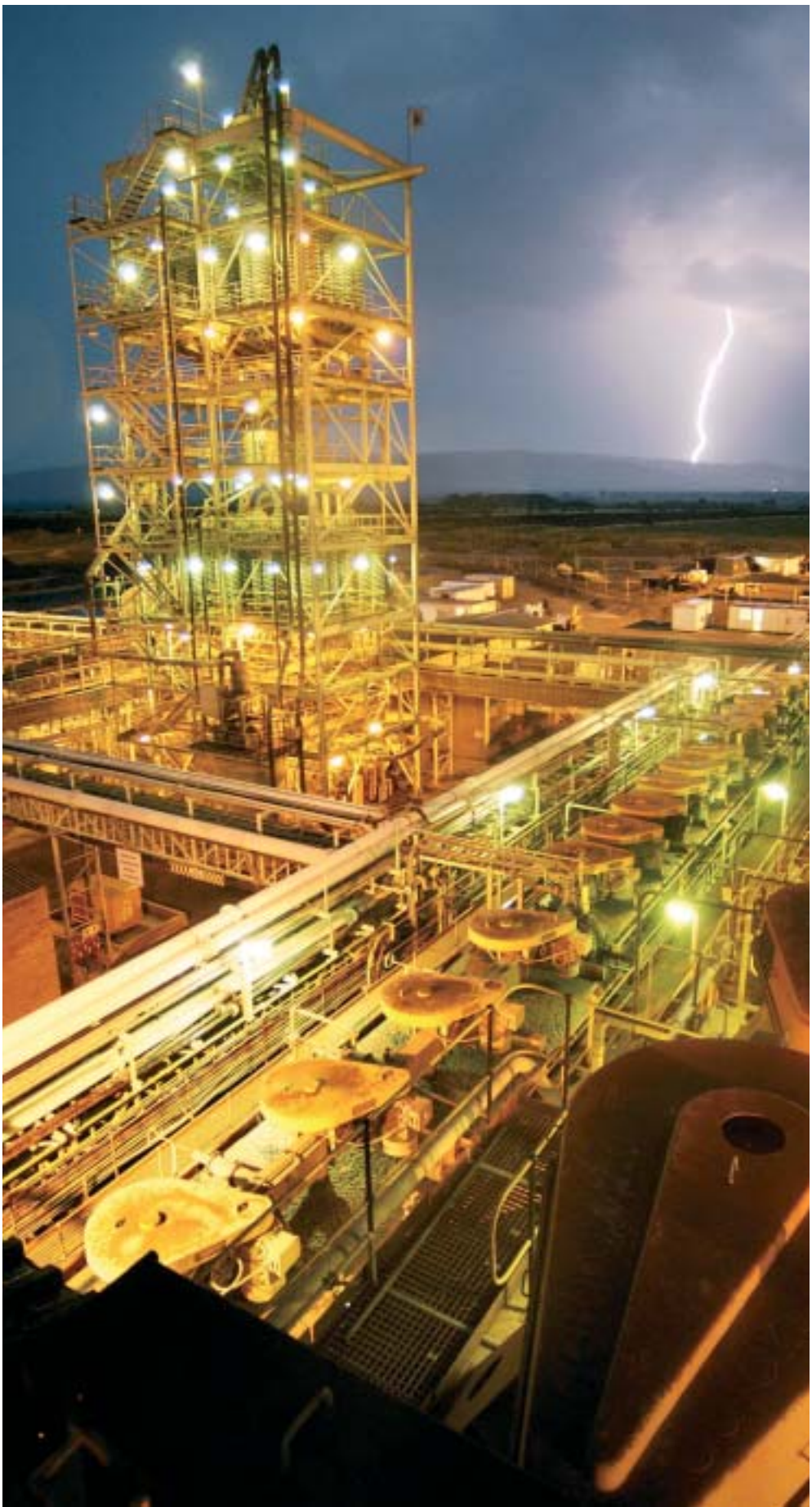
The physical palladium market, therefore, will remain in substantial surplus in 2004. As was demonstrated during the first four months of the year, however, the price of palladium has become largely divorced from the fundamentals of supply and demand. The weight of speculative investment has been responsible for supporting the price, and additional substantial buying by funds would have the capacity to drive it back to recent highs. On the other hand, any further concerted long liquidation of the still very large speculative positions could lead to a sharp correction downwards. On balance, we believe that palladium is likely to trade between $200 and $340 over the next six months.



The volume of palladium recovered from scrapped autocatalysts climbed by 11 per cent in 2003 to 410,000 oz, and is forecast to rise even more rapidly in 2004.



Supplies



View of Aquarius Platinum's Kroondal plant at dusk. The operation produced a total of 216,000 oz of pgm in 2003.

A new, higher capacity converting process plant, which will substantially reduce sulphur dioxide emissions, and a slag cleaning furnace were commissioned at Anglo Platinum's Waterval Smelter in 2003.

Supplies

Supplies, Mining and Exploration

South Africa

Total supplies of platinum from South Africa climbed by 5 per cent in 2003 to 4.67 million oz. Refined platinum output at Anglo Platinum grew modestly to 2.3 million oz, less than had been expected at the start of the year; production from Impala was steady, whilst mining rates increased at all the other producers. Palladium shipments grew by almost 7 per cent to 2.31 million oz, whilst rhodium sales climbed to 545,000 oz.

Anglo Platinum

Anglo Platinum's output of refined platinum reached 2.3 million oz in 2003, up from 2.25 million oz in 2002 but 100,000 oz less than anticipated. The shortfall was due to a slower than planned ramp up of operations at developing mines plus a larger than expected increase in pipeline stocks of metal. This was related to the concurrent commissioning of three new metallurgical facilities: a smelter at Polokwane, and the Anglo Platinum Converting Process (ACP) and a slag-cleaning furnace at Rustenburg.

At Anglo Platinum's Rustenburg section (consisting of the West Mine, East Mine, and the developing Waterval Mine), production fell from established mining areas due to a decline in available Merensky Reef ore reserves but this was more than offset by a 51 per cent jump in tonnage milled at Waterval and an improvement in grades under phase 1 of the Rustenburg UG2 project. Total refined platinum output attributable to the Rustenburg mines climbed by almost 7 per cent to 826,000 oz.

At Amandelbult, increased mining of UG2 ore and lower Merensky Reef output resulted in a decline in overall grades and recoveries, and platinum output slipped to 645,000 oz. At Union section, however, increased UG2 concentrator capacity enabled an expansion in production, whilst output at Lebowa was steady. Operations at PPRust improved significantly in 2003 as the Zwartfontein South Pit came into production, giving access to higher grade ore and raising the overall head grade. The developing Bafokeng-Rasimone Platinum Mine achieved a substantial increase in underground mining efficiencies in 2003. With average grades and recoveries also increasing, equivalent refined platinum production climbed by more than 13 per cent to 184,000 oz.

Production at the Modikwa project, a joint venture between Anglo Platinum and a consortium led by African Rainbow Minerals, continued to build in 2003 but failed to meet target due to adverse geological conditions, lower than expected mining efficiencies and poor face availability. Production is expected to expand significantly in 2004, reaching the planned maximum rate equivalent to 162,000 oz of refined platinum by the end of the year. The group's new tailings reprocessing plant near Rustenburg was commissioned towards the end of 2003. Phase 1 of the project is expected to yield an annual average output of 70,000 oz of platinum between 2004 and 2006.

Two new projects were announced by Anglo Platinum during 2003: the Pool and Share Agreement (PSA) with Aquarius Platinum at Kroondal, and the development of a new mine at Unki in Zimbabwe *(see Zimbabwe section on page 23)*. Under the PSA, the assets of the Kroondal Platinum mine were combined with contiguous UG2 reserves at Anglo Platinum's Rustenburg section. Production at Kroondal will be doubled to reach a rate of 505,000 oz pgm per annum in 2006 (split equally between the two partners), with Anglo Platinum due to start taking concentrate from the operation in 2005.

The sharply increasing strength of the rand during 2003, coupled with rising local costs and inflation, and relatively weak prices for palladium and rhodium, caused Anglo Platinum to re-evaluate its long-term expansion programme. The group subsequently decided to slow the development of several projects, notably the planned mines at Twickenham and Der Brochen on the eastern limb of the Bushveld Complex, and a planned expansion of the new tailings retreatment plant. The target of producing 3.4 million oz of refined platinum in 2006 was scaled back to 2.9 million oz.

Impala Platinum

Impala Platinum's production of refined platinum from its lease area on the western limb of the Bushveld Complex remained fairly steady in 2003 at a little over 1 million oz. Production from new declines came on stream during the year and the company also exploited shallow Merensky Reef ore reserves via open cast mining, helping to offset the effects of a strike in March. A new tailings scavenging plant, commissioned in December, will boost overall recoveries by 1 per cent (around 10,000 oz platinum per year).

PGM Supplies: South Africa
'000 oz

	2002	2003
Platinum	4,450	4,670
Palladium	2,160	2,310
Rhodium	490	545

Supplies

Construction of the concentrator at Impala Platinum's Marula operation on the eastern limb of the Bushveld Complex was completed in late 2003.

Construction of the Marula mine on the eastern Bushveld continued during the year but worse than expected geological conditions meant that development of drives and stopes fell behind schedule. The concentrator at Marula entered commissioning in early January 2004 and will initially process stockpiled ore. The operation is scheduled to reach full capacity in 2005, by which time it is expected to be producing 100,000 oz per year of platinum.

Impala halted mining operations at the Crocodile River UG2 mine in November 2003 after experiencing severe difficulties in trying to move to wholly underground mining. Geological conditions were extremely challenging, leading to a much slower rate of development than anticipated. In addition, profitability was hampered by the strength of the rand and low palladium and rhodium prices.

In March 2004, Impala announced that a consortium headed by Salene Platinum Holdings had agreed to acquire its entire 83 per cent holding in Barplats, the company that controls the Crocodile River operation.

In October 2003, Impala and African Rainbow Minerals approved a small-scale trial mining project at their Two Rivers joint venture on the eastern Bushveld. A final decision on whether to proceed with the full-scale development of a mine is expected in mid-2004.

Impala committed to the sale of its 27 per cent interest in the operations of Eastern Platinum Ltd and Western Platinum Ltd (Lonmin owning the balance) in 2003. Under the deal, which had not been finalised as of April 2004, Lonmin will acquire a further 9 per cent stake in the operations from Impala and the remaining 18 per cent will be vested into a new company (Incwala) to be controlled by Black Economic Empowerment (BEE) shareholders. Impala also raised its stake in Zimbabwe Platinum Mines Ltd (Zimplats) to 82.5 per cent during the year (*see Zimbabwe section*).

Lonmin

Lonmin's mining operations performed strongly in 2003; the volume of ore milled climbed by 26 per cent during the company's 2003 financial year (to 30th September) to exceed 14 million tonnes. The introduction of open cast mining of UG2 reserves contributed most of the additional ore, and UG2 head grades and recoveries were higher than projected. There was also a moderate increase in production from underground operations. Production of refined platinum consequently rose by 21 per cent to 916,000 oz, although this total included some 30,000 oz that was sourced from the processing of refinery residues.

The company's new smelter was out of service for almost the whole of 2003 due to an explosion that occurred in December 2002. Concentrate was processed through Lonmin's older pre-existing furnaces and via a toll smelting agreement with Impala. Recommissioning of the repaired and modified smelter began in late December 2003.

The Pandora project, to the east of Lonmin's existing operations, is at an early stage of development. The joint venture between Lonmin and Anglo Platinum originally included Northam Mining and the Bapo Ba Mogale Tribe as minority BEE partners holding a 5 per cent interest each. In March 2004 the Pandora joint venture was restructured to increase the BEE component, with the equity interest to be held by Northam increased to 7.5 per cent and transferred to Mvelaphanda Resources Ltd (a major shareholder in Northam and a recognised BEE entity). The shareholding will be returned to Northam once the company qualifies as meeting the full equity requirements of BEE legislation.

Northam Platinum

Northam Platinum produced a total of 326,000 oz of pgm in concentrate in 2003 (platinum accounting for 206,000 oz), up from 315,000 oz of pgm the previous year and the company's highest annual total to date. The growth was a result of an increase in the volume of ore milled plus an improvement in the overall head grade. The latter was due in part to Northam's focus on prioritising the development and mining of the Merensky Reef ahead of UG2 reserves, which have a lower average pgm grade. Merensky Reef climbed as a proportion of total ore mined from 69 per cent in 2002 to 71 per cent in 2003. Output of pgm in 2004 is expected to be broadly similar to that in 2003.

In February 2004, Mvelaphanda Resources acquired a BEE consortium named Khumama Platinum that held 50 per cent participation rights in the Booysendal joint venture with Anglo Platinum. Mvela will transfer the Khumama interest in Booysendal (located on the eastern limb of the Bushveld Complex) to Northam in return for a combination of cash and shares, which will result in Mvela increasing its stake in Northam

from just over 22 per cent to 34 per cent.

The Booysendal project itself lies immediately to the south of Anglo Platinum's wholly-owned Der Brochen lease area and contains resources of 47.6 million oz pgm within the Merensky Reef and a further 76.8 million oz of pgm in the UG2 horizon.

Aquarius Platinum

Aquarius Platinum produced a total of 183,000 oz of platinum in concentrate in 2003, up by more than a third compared with 2002. The increase was largely due to the ramp up of production and an increase in recoveries at the new Marikana operation, plus expanded output at the Mimosa joint venture in Zimbabwe. At Marikana, however, face availability in the open pits remained limited and the mine had yet to achieve consistency in the quality of feed supplied to the concentrator.

The Kroondal mine faced a number of geological problems during the first half of 2003 that reduced output but production accelerated during the third and fourth quarters under a continuous improvement programme. Total platinum production in concentrate for the full year increased to almost 133,000 oz.

The Pool and Share Agreement (PSA) between Anglo Platinum and Aquarius at Kroondal began on 1st November 2003, although in the short term concentrate will continue to be sold to Impala for refining. Anglo Platinum will begin to treat concentrate from the project in 2005, and expects to be handling 100 per cent of the expanded mine's output by 2008. A new 250,000 tonne per month concentrator will be constructed, with commissioning due in June 2005, and a third decline will be established to access Anglo Platinum reserves just to the east of the current Kroondal mine.

Aquarius's pgm production will also be lifted by a chromite tailings project, announced in March 2004. A consortium comprising Aquarius (50 per cent), GB Mining & Exploration (25 per cent) and Sylvania South Africa (25 per cent) will construct a new plant to extract pgm from tailings from chromite mines in the Kroondal area. Production from the plant is scheduled to start in October 2004 and it is expected to yield up to 28,000 oz pgm per year.

In December 2003, Aquarius announced a BEE transaction with a group of investors led by Savannah Resources (Pty) Ltd. Under the deal, a 26 per cent share in Aquarius Platinum South Africa will be sold to the consortium for R860 million, subject to the completion of a financing package. Aquarius will then be fully compliant with the equity ownership component of the South African Mining Charter. Funds raised through the transaction will be used to finance the development of the Everest South project, construction of which is due to start in mid-2004 with production from late 2005.

Aquarius holds a 50 per cent interest in ZCE Platinum (Impala holding the balance), which operates the Mimosa mine in Zimbabwe. A major expansion of the underground mine and concentrator at Mimosa neared completion in 2003, driving a substantial increase in pgm output *(see Zimbabwe section)*.

SouthernEra

Production at the Messina project, majority-owned by the Canadian-based SouthernEra Resources, totalled 56,600 oz of pgm plus gold in 2003. Production at the phase 1 (Voorspoed) section built steadily throughout the year, climbing from 72,000 tonnes of ore in the first quarter to over 188,000 tonnes of ore during the fourth quarter. The mine is likely to hit its target ore production rate of 120,000 tonnes per month (equivalent to approximately 160,000 oz pgm per year) during the third quarter of 2004.

A feasibility study on phases 2 and 3 of the Messina project, based on the development of a new 240,000 tonne per month mine producing 340-360,000 oz pgm per year, is due to be completed by mid-2004. In April 2004, SouthernEra announced that it was considering separating its platinum interests from its diamond mining and exploration holdings by forming two separately listed public companies.

Russia

Sales of platinum, palladium and rhodium by Russia in 2003 once again exceeded mine production. At 1.05 million oz, platinum sales were 7 per cent higher than in 2002; palladium sales jumped by 53 per cent to 2.95 million oz as Norilsk Nickel sold all its output, in contrast with 2002 when the company withheld part of its production. Rhodium sales accelerated to 140,000 oz, an increase of 56 per cent.

In November 2003 President Putin approved a bill to relax the severe restrictions that apply to all information about reserves, production and sales of pgm in Russia.

The strength of the rand, and low palladium and rhodium prices, made the economics of the many pgm exploration projects in South Africa less attractive in 2003.

PGM Supplies: Russia
'000 oz

	2002	2003
Platinum	980	1,050
Palladium	1,930	2,950
Rhodium	90	140

Russian PGM

PGM Mining in Russia

Russia currently accounts for over 40 per cent of global annual mine production of palladium and approximately 15 per cent of platinum production. Despite the importance of the Russian pgm mining industry to global pgm markets, hard facts on reserves, production and sales have historically been difficult to come by, as data was deemed confidential under the Russian state secrecy law.

In recent years, however, Norilsk Nickel has been able to disclose more information regarding its base metals operations, and the group has been pushing for the freedom to publish details of its pgm reserves, production and sales. These efforts bore fruit in late 2003 when a bill to declassify pgm information (with the exception of government stocks and sales) was passed by both chambers of the Russian parliament and was signed by President Putin.

The bill took effect in February 2004 but the publication of pgm data appears to have been delayed by regulatory procedures that have to be completed by several ministries. Release of pgm information is now not expected until the final quarter of 2004 at the earliest.

In the meantime, this article describes the structure and mining operations of Norilsk and the alluvial pgm producers in Russia, and provides estimates of current platinum and palladium output. The latter are based on data from a wide range of sources, including visits made by Johnson Matthey staff to the facilities described.

View of part of the ore milling circuit at Norilsk Nickel's Talnakh concentrator.

Map of Russia showing location of pgm mining districts and pgm refineries.

Russian PGM

Norilsk Nickel: a pgm powerhouse

Norilsk Nickel dominates Russian pgm output, producing platinum, palladium and minor pgm from its copper-nickel mining and smelting complex in northern Siberia. Small volumes of pgm are also produced from its copper-nickel mines in the Kola Peninsula.

Detailed exploration and research into the copper-nickel ore deposits in the Taimyr Peninsula in northern Siberia began in the 1920s. Development of the Norilsk Combine began under the aegis of the Soviet security services in 1935, utilising political prisoners and convicts as labour. Initially adits were dug to exploit the Norilsk copper-nickel-pgm deposit and the first copper-nickel matte was produced in March 1939 from a pilot facility. Two open pit mines were established in the 1940s and by 1953 the combine was producing 35 per cent of the Soviet Union's total nickel output, 12 per cent of its copper, 30 per cent of its cobalt and 90 per cent of its platinum group metals.

Over the next three decades the mines and associated processing facilities at Norilsk underwent several major expansions. Crucial to the area's development was the discovery in 1960 of huge, high-grade ore resources at Talnakh, approximately 25 km north of Norilsk. Production expanded rapidly during the 1960s and 1970s with the construction of new mines and a concentrator to process the Talnakh ores. This was followed in the early 1980s by the establishment of a smelting complex at Nadezhda. By the late 1980s palladium output exceeded 4 million oz per year.

Following the break up of the Soviet Union in 1991, the operations at Norilsk experienced a difficult period – with a lack of capital for investment the mining and processing infrastructure deteriorated, whilst domestic demand for base metals and palladium slumped. Consequently, by 1996 palladium output was estimated to have fallen below 2 million oz.

Map of local area of Norilsk showing location of copper-nickel-pgm mines and processing facilities.

In 1997 a controlling share in the company was acquired by Uneximbank through an associated investment company. The access to new capital enabled Norilsk to pay off substantial debts to the state pension fund and resume investment in its facilities. Revenues were also boosted by the devaluation of the rouble in 1998 and, over the next three years, by the increasingly rapid rise in the palladium price, which encouraged an emphasis on improving recoveries of the metal. As a result palladium output at Norilsk climbed to an estimated 2.7 million oz by 2000 and has remained fairly close to this level since then.

The Norilsk Nickel group today consists of three main operating divisions, two of which concern copper-nickel-pgm production, the other relates to gold. The Polar Division, located on the Taimyr Peninsula in northern Siberia, operates seven nickel-copper mines and associated metallurgical plants, and is the source of most of the company's pgm production. The Kola Mining and Metallurgical

Drilling underground at Norilsk Nickel's Oktyabrsky mine in northern Siberia, source of much of the company's pgm production.

Russian PGM

Company on the Kola Peninsula mines and processes lower grade nickel-copper deposits containing small amounts of by-product pgm, and also processes some high-grade matte that is shipped in from the Polar Division. Finally the group has a rapidly expanding gold division, which incorporates the Olimpiada mine in the Krasnoyarsk region, operated by ZAO Polyus, and majority shareholdings in the Matrosov (Magadan) and Lenzoloto (Irkutsk) deposits.

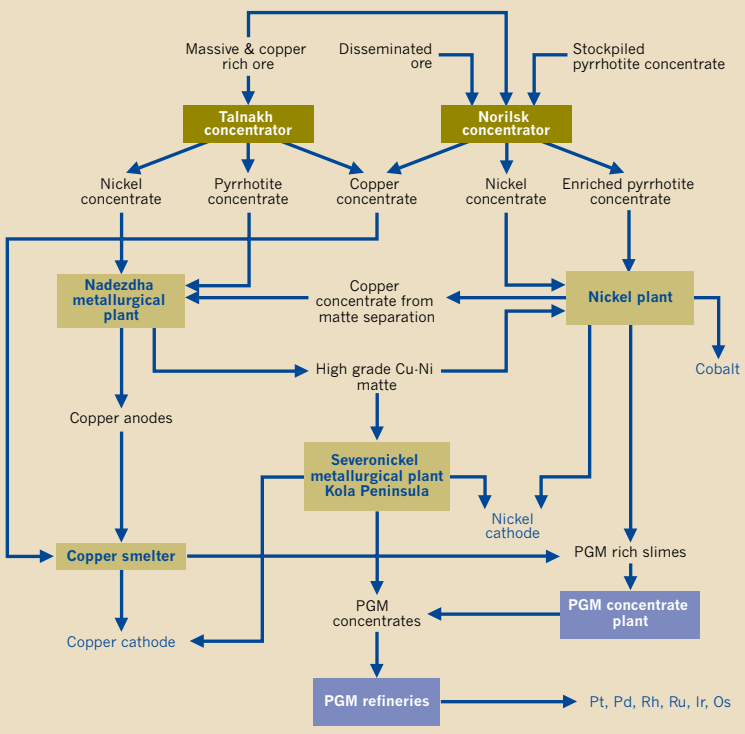
Polar pgm

The scale of Norilsk Nickel's Polar Division operations is impressive – especially in view of the remote location and the hostile conditions. The town of Norilsk is located inside the Arctic Circle, where the average daily temperature in February is -32° Celsius, and it is completely isolated from Russia's road and rail systems. The Yenisey River, which links the Norilsk area with Krasnoyarsk some 1,500 km to the south, is navigable during the summer but in winter the site is accessible only by air or via the northern sea route (kept open with ice-breakers) between Dudinka and Murmansk on the Kola Peninsula.

Despite these challenges, in 2002 (the last year for which official data are available) the Polar Division mined and processed just over 13 million tonnes of ore from its six underground mines and one open cast operation at Norilsk-Talnakh. We estimate that total pgm output reached 650,000 oz of platinum, 2.7 million oz of palladium, and 60,000 oz of rhodium. These figures include small amounts of pgm from Norilsk Nickel's operations on the Kola Peninsula, but the volumes are understood to be negligible – probably no more than 20,000 oz per annum in total.

Tapping molten palladium at the Krastvetmet pgm refinery in Krasnoyarsk

Norilsk Nickel Polar Division - Simplified Processing Flowsheet



A unique suite of pgm deposits

The deposits mined by Norilsk Nickel's Polar Division are unique in their size and are unusually rich in pgm. We estimate that head grades at Norilsk-Talnakh mines average between 10 and 11 grams per tonne pgm – more than twice the typical grade of ore mined in South Africa – in addition to high base metal values of around 1.8 per cent nickel and over 3 per cent copper.

The Norilsk-Talnakh ore bodies occur as large sheets or pods associated with a sequence of layered igneous intrusions. The deposits are considerably wider than the narrow, continuous reefs mined in South Africa, but are much more variable in grade and composition. Consequently, even within a single mine, pgm grades can vary widely.

Three types of ore are mined:

Massive sulphide ores occur in lens-shaped ore bodies typically between 1 and 40 metres thick, and are the richest in nickel. They can also contain extremely high pgm values – up to and beyond 100 g/t in some areas – though a more typical grade would be 12-14 g/t pgm with a palladium to platinum ratio of between 3:1 and 4:1.

Copper-rich ores form a halo around the massive sulphide lenses. They tend to be significantly richer in copper than the massive sulphide ore, but with a relatively low nickel grade. They

often contain large amounts of platinum and palladium; indeed, grades for these metals can be as high as those in the massive ores.

Wide zones of **disseminated ores**, up to 40 to 50 metres thick, are also associated with the intrusive bodies. These are less rich in both base and precious metals but nevertheless can contain grades of between 5 and 15 g/t pgm.

Mining at Norilsk-Talnakh

There are currently five operating mines at the Talnakh deposit, all of which are underground, and two at the older Norilsk-I deposit including one open cast operation (see map on page 17).

The jewel in Norilsk's crown is the **Oktyabrsky** mine, which in 2002 accounted for 36 per cent of the ore mined by the Polar Division but 49 per cent of the nickel and 53 per cent of the platinum and palladium. This mine extracts some 4.7 million tonnes of ore per annum, of which around 4 million tonnes are rich, massive sulphide material with a high pgm content – probably averaging 13-14 g/t. It also mines small but increasing quantities of copper-rich ore, and a little disseminated ore.

There are two other full-scale mines exploiting the Talnakh deposit: the **Taimyrsky** mine, which in 2002 mined only massive sulphide ore, and the **Komsomolsky** mine, which extracts mainly copper-rich ore. In addition, smaller contributions to production are made by the **Mayak** mine, the oldest and smallest operation at Talnakh, and the new **Skalisty** mine which is exploited via the Komsomolsky infrastructure. The latter is currently building up to full production, expected to be around 1 million tonnes per annum of pgm-rich massive sulphide ore. Both Mayak and Skalisty are now managed as part of the overall Komsomolsky operation.

At the Norilsk-I deposit the massive sulphide ore has long been exhausted, and only disseminated ore is mined, via the **Zapolyarny** underground mine and the **Medvezhy Ruchey** open pit.

From ore to metal

Norilsk Nickel's Polar Division operates two 'enrichment plants' (concentrators) and three metallurgical plants (incorporating smelting, base metal refining and the upgrading of pgm residues). A simplified outline of the processing flow sheet is shown opposite.

The Talnakh Enrichment Plant, which came into operation in 1980, processes the majority of the massive sulphide ores and some copper-rich material to produce nickel, copper and pyrrhotite (iron sulphide) concentrates. Between 1980 and the late 1990s, much of the pyrrhotite concentrate was stockpiled, as the company's metallurgical plants could not treat it effectively. This had quite a significant impact on production, as around 10 per cent of the nickel and quite substantial amounts of pgm were lost through association with the pyrrhotite fraction.

More recently Norilsk Nickel has been treating all current arisings of pyrrhotite concentrate via an oxidative leach process at the Nadezhda Smelter. It has also begun to upgrade some of its pyrrhotite stockpile through the Norilsk Enrichment Plant – 750,000 tonnes were processed in 2002, although very large stocks are still believed to exist. The Norilsk concentrator (the older of the two, parts of which date from the 1940s) also treats the remaining disseminated, massive and copper-rich ores to produce nickel and copper concentrates.

Nickel and pyrrhotite concentrates from the Talnakh Enrichment Plant are sent to the Nadezhda Smelter, while the Norilsk concentrator's output is sent to the Nickel Smelter. Copper concentrates from both plants are processed at the Copper Smelter. Adjacent to the latter is the precious metals concentrate production area, which upgrades slimes from electrolytic refining operations at both the Nickel and Copper plants. The resulting product, now rich in platinum group metals, is sent for toll refining at independent precious metals refineries, primarily the Krastsvetmet refinery in Krasnoyarsk. Traditionally most of Krastsvetmet's pgm output was in the form of ingots but since 1999 a significant portion of production has been as sponge.

Production Plan to 2015

In March 2003, Norilsk Nickel published its Production Plan to 2015. The aim of the plan is to enable the company to respond to market demand for its metals, while increasing efficiencies and limiting the environmental impact of its operations. The company's

Pouring molten copper-nickel matte at Norilsk Nickel's Nadezhda smelter.

Russian PGM

At Kondyor pgm-bearing river sediments are broken up with high pressure water jets. Lighter clay and sand particles are washed away over screens, leaving the heavier platinum grains behind.

immediate goal is to increase production from the Norilsk-Talnakh mines to around 14 million tonnes of ore per annum, which represents a 7 per cent increase compared with the 13.06 million tonnes extracted in 2002. Output from the Kola Peninsula operations will fall to 6 million tonnes, keeping the overall level of production stable at 20 million tonnes.

Between 1998 and 2002, the mining of disseminated ore at the older Norilsk-I mines increased by 40 per cent, as the surge in palladium prices made it economic to mine this ore for its pgm values (it is marginal when considered as a base metal ore). However, the new production strategy will reverse this trend, with output of disseminated ore declining in favour of a modest increase in mining of massive sulphide material and a significant jump in the extraction of copper-rich ore. Output of the latter was below 1 million tonnes per annum in 1998, reached almost 3 million tonnes in 2002, and is planned to expand to 5 million tonnes in 2005 under the current Production Plan.

As a result of the planned change in the mix of ores mined, nickel output from the Taimyr Peninsula is expected to rise to 200,000 tonnes per annum from 185,000 tonnes in 2002, an increase of 8 per cent. The company has stated that pgm production will remain approximately constant, but we think it likely that the overall increase in ore production at Norilsk-Talnakh, combined with the shift towards copper-rich ore, will boost pgm output in excess of the growth in base metals production.

A further increase in pgm and base metal output is possible. Norilsk Nickel has stated that it could increase ore production from the Norilsk-Talnakh mines to 20 million tonnes per annum if market conditions were favourable. However, this would require substantial additional investment, not only in the mines but also to overcome capacity constraints at the concentrators. A decision on whether to commit funds to such an expansion is likely to be made in 2005. The company could also accelerate the rate at which it processes stockpiled pyrrhotite concentrate but again this would require additional investment in processing capacity.

On the metallurgical side, Norilsk Nickel plans to upgrade its smelting facilities at Nadezhda and the Copper plant, which will permit the closure of the smelter at the Nickel plant. Not only will this result in lower smelting costs, it will also help reduce sulphur dioxide emissions substantially.

Research is currently underway to assess further possible investments in processing infrastructure. These include new flotation technology with the potential to increase recoveries by up to 5 per cent and the introduction of high-grade matte leaching-refining technology at Nadezhda.

Recovery of egg-sized nuggets of platinum is not uncommon at Kondyor; the largest nugget recovered from the operation to date weighed a massive 3.52 kg.

Rivers of platinum: alluvial mining in the Far East of Russia

In recent years significant quantities of platinum have been produced from two alluvial operations in the Far East of Russia. The larger of these, Kondyor, is located in a crater-like bowl surrounded by mountains in the Ayano-Maisk region of Khabarovsk (*see map on page 16*). The Koryak deposit is found on the Kamchatka Peninsula. Both operations are remote and experience harsh winter weather; consequently, mining takes place only during the summer season, usually from May to September.

The existence of platinum at **Kondyor** was first confirmed in 1957 but it was initially calculated that the deposit contained just 2 tonnes of metal and, given the remote location, was therefore uneconomic. As a result it was more than 20 years before the potential of Kondyor was fully appreciated. In 1978 and 1979 a detailed re-evaluation of the area's platinum potential resulted in the collection of numerous platinum nuggets. This was followed by a

Russian PGM

trenching and sampling campaign in 1980 and 1981 that was undertaken by a local gold mining company, the Amur artel. Commercial exploitation of the deposit by Amur began in 1984 with the extraction of 60 kg of platinum; by 1987 production had reached 1 tonne. According to the company, the level of production has been more or less stable since 1990 at around 3 tonnes (~95,000 oz) of platinum per annum, although recent reports suggest that output may have risen to closer to 4 tonnes (~130,000 oz) in 2003. It is thought that production in the range of 3 to 4 tonnes per year is sustainable for some years to come.

The processing method at Kondyor is relatively simple because the platinum occurs in discrete grains. Bulldozers scrape out the bottom of the riverbed and drive the material to sluices in which hydraulic guns break up and wash the ore allowing heavier particles to fall through a mesh into collectors. The artel currently has 14 of these hydraulic units in operation. There follows further on-site washing stages to separate out the precious metal grains (in effect, panning on an industrial scale). These are collected and are passed through a final gravity concentration stage and a shaking table to separate pgm and gold concentrates. The platinum grains can be extraordinarily large: the largest nugget found so far weighed 3.522 kg (around 110 oz) with a metal content worth in the region of $100,000 at today's prices.

The Koryak alluvial operation is located on the Pustaya river system, which drains an area of pgm-bearing zoned ultrabasic rocks in the Kamchatka Peninsula in the Far East of Russia. Prospecting took place from 1990 and in 1994 the Chaibukha Mining Artel won a tender to enter into a 25 year mining licence agreement with Koryakgeologodobycha (KGD). Trial mining at two sites began that year and full-scale operations started in 1995.

The mining and processing operations at Koryak are similar to those at Kondyor, encompassing mining of river gravels by bulldozer followed by a series of washing and gravity separation stages to concentrate the platinum grains.

River sediment at Koryak is channelled down sluices, allowing dense platinum grains to settle out. These are collected manually before undergoing further washing prior to bagging and dispatch by air to a pgm refinery.

View across the Pustaya river valley in Kamchatka, source of KGD's alluvial platinum.

Production peaked in 1998 at close to 7 tonnes of platinum but then halved the following year after a dispute between Chaibukha Mining and KGD resulted in their agreement being dissolved. Chaibukha subsequently transferred its mining equipment from Koryak to gold projects in Irkutsk. KGD continues to mine the Koryak alluvial platinum deposits but output is believed to have fallen to between 2 and 3 tonnes (65,000 to 95,000 oz) annually. The reserves at Koryak are understood to be smaller than those at Kondyor, with the richest deposits having already been depleted.

The Urals – potential from the past

Large alluvial platinum deposits were discovered in the central Ural Mountains in 1823 and mining in the area grew rapidly. By the end of the 19th century the alluvial deposits of the central Urals had become the world's dominant source of platinum. The most easily accessible high-grade placer deposits, however, had largely been exhausted by the end of the 1920s and mining has since dwindled to a handful of small-scale dredging operations producing very modest volumes of platinum.

The Urals region remains of interest, however, as a potential future source of platinum. Exploration is examining the possibility of exploiting alluvial platinum in the central Urals area that was too fine-grained to have been recovered by former mining operations. Previously unmined placer deposits that have been buried under sediment may also exist, whilst the poorly explored northern Urals area offers the potential to host as yet undiscovered alluvial platinum fields.

Estimated Russian Mine Production of Platinum and Palladium in 2003
'000 oz

	Pt	Pd
Norilsk	650	2,700
Amur artel, Kondyor	130	0
KGD, Koryak	90	0
Urals	10	0
Total	**880**	**2,700**

However, in February 2004, when the bill was due to come into effect, it was announced that further approvals would be required. It is not entirely clear what these are, but amendments to regulations published by the Ministries of Finance and Natural Resources have been quoted. It has also been suggested that pgm are still classed as strategic materials and that this too must be amended. It seems clear that publication of pgm data by Norilsk Nickel and others will not occur for some time.

As outlined in the accompanying special feature, we estimate Russian production of platinum in 2003 was around 880,000 oz, palladium around 2.7 million oz and rhodium about 60,000 oz. Sales were somewhat higher than these figures, with the extra metal presumably coming from stocks held by government agency Gokhran or possibly from the Central Bank. There appears to have been particularly aggressive sales of rhodium, with substantial amounts of the metal being shipped to the USA during the year. Some of this metal may have ended up in the hands of consumers, but the heaviest users of rhodium are the auto companies and there were no indications that they were adding to pgm stocks during 2003.

In our 2003 Russian data we have not included any of the 877,169 oz of palladium that were used by Norilsk Nickel as part of the purchase price of the shareholding it acquired in Stillwater Mining in June last year. Although the metal was exported from Russia, Stillwater indicated that none of this metal was sold in 2003 and, therefore, it had no direct impact on the supply/demand balance. The company did report, however, that the majority of this metal will be sold in 2004 and 2005 and we will take this into account in our supply figures for these years.

North America

Shipments of platinum from North American producers dropped by a quarter in 2003 to 295,000 oz. The fall was almost entirely due to much lower production from Inco, which resulted from a three month strike and the depletion of certain pgm-rich ore reserves. Palladium output in the region fell less dramatically, slipping by 5 per cent to 940,000 oz. Reduced production from both Inco and Stillwater Mining was partially offset by higher output at North American Palladium, which mines an ore body that contains a very high proportion of palladium.

PGM Supplies: North America
'000 oz

	2002	2003
Platinum	390	295
Palladium	990	940
Rhodium	25	20

Canada

North American Palladium processed over 5 million tonnes of ore from its Lac des Iles open pit at an average palladium grade of 2.31 grams per tonne in 2003 compared with 4.85 million tonnes of ore at 1.96 grams per tonne in 2002. Production of palladium in concentrate climbed to 289,000 oz, an increase of nearly 32 per cent year-on-year. The substantial growth in output was due to the successful commissioning of a new primary crusher in June, which improved throughput and mill availability, while head grades increased as a result of mining of higher grade ore zones during the second half of the year.

A secondary crushing circuit will be installed during 2004 to help maintain output close to 2003 levels. In March 2004, the company announced that it would proceed with the development of an underground mine at the Lac des Iles mine that will exploit a higher grade sub-vertical ore body located directly beneath the open pit. Construction is due to start by the middle of the year with first ore production in the second half of 2005. The underground mine and the open pit will operate in tandem, yielding around 300,000 oz per year of palladium in total.

Inco's production of 90,000 oz of platinum and 108,000 oz of palladium in 2003 was significantly lower than in recent years because of a three month strike at the company's Sudbury operations during the summer and the depletion of one of the pgm-rich ore zones at its Copper Cliff North mine. Output is expected to recover to around 400,000 oz of pgm in 2004 as the company prioritises the development of other pgm-rich ore bodies at its Sudbury operations.

The quantity of ore mined at Falconbridge's Sudbury operations declined slightly to 2.23 million tonnes in 2003, while nickel grades also declined. However, precious metals production and sales increased, reflecting improved metallurgical recoveries, particularly at the company's smelter. An increasing focus on higher pgm grade areas and changes in the refining pipeline may also have contributed to the increase.

In March 2004, Falconbridge announced its decision to proceed with an underground exploration and development programme at the Nickel Rim South deposit in the Sudbury basin. The deposit contains significant pgm grades: inferred resources of 13.2 million tonnes average 1.7 per cent nickel, 1.9 grams per tonne platinum and 2.2 grams per tonne

palladium. The development programme will cost around $400 million and is expected to lead to the start of full-scale production in 2008.

USA

Stillwater Mining Co. produced 450,000 oz of palladium and 134,000 oz of platinum in 2003, around 5 per cent below the level of production projected at the beginning of the year and down from 476,000 oz and 141,000 oz respectively in 2002. Output at the Stillwater Mine declined by 13 per cent following a drive to reduce costs, but this was partly offset by an increase in production from the newer East Boulder mine. Total production in 2004 is expected to be in the range of 610,000 to 625,000 oz pgm.

The acquisition by Norilsk Nickel of a 50.8 per cent shareholding in Stillwater Mining in exchange for $100 million and 877,169 oz of palladium was completed in June 2003, with Norilsk subsequently raising its stake to 55.5 per cent. In February 2004, Stillwater announced that it had entered into contracts or had reached understandings, under which all of the palladium will be sold, primarily for use in automobile catalytic converters, at close to market prices over a period of two years, commencing in 2004 *(note: this metal will be recorded as Russian supply not North American supply in our figures)*.

Zimbabwe

Platinum production in Zimbabwe climbed to 140,000 oz in 2003, almost double the previous year's total as mining at both the Mimosa and Ngezi mines continued to expand. The Zimbabwe government began the process of drafting black economic empowerment legislation but there is considerable uncertainty over the final form the regulations will take.

In 2003, production continued to ramp up from the Ngezi mine (effectively controlled by Impala but operated by Zimplats via Makwiro Platinum Mines (Pvt) Ltd), and it had neared its full operating rate by the end of the year. The operation at Ngezi milled just less than 2 million tonnes of ore, yielding approximately 170,000 oz of pgm and gold, an increase of 43 per cent on 2002. A total of 42 production days were lost at the company's smelter between July to September following a breakout of molten metal but the resulting stockpile of concentrate was processed before the end of the year.

A 42-metre long road train loaded with ore leaving Zimplat's Ngezi mine for the Selous Metallurgical Complex.

Zimplats is undertaking a bankable feasibility study of an expansion that would encompass the construction of an underground mine and a new concentrator at Ngezi (ore is currently trucked to a concentrator plant at Selous for processing). Total mill throughput would rise to 3 million tonnes per year, increasing precious metals production to around 270,000 oz pgm plus gold per year. Trial underground mining began during the first quarter of 2003 and output and grades improved throughout the year.

In September 2003, Zimplats announced that it had entered into a heads of agreement with Needgate Investments (Pty) Ltd, a Zimbabwean empowerment consortium, under which Needgate would acquire up to a 15 per cent shareholding in the company by way of a new share issue. As of April 2004 financing discussions were continuing.

Expansion of the Mimosa mine (a 50:50 joint venture between Aquarius and Impala) continued rapidly during 2003. The operation milled 1.2 million tonnes of ore during the year, a more than three-fold increase compared with 2002. Output of pgm in concentrate totalled 106,000 oz, of which platinum accounted for 59,000 oz. These results reflected the first full year of operation of the company's enlarged concentrator. A feasibility study to assess a further doubling of production is due for completion by December this year.

Anglo Platinum's Unki project, located near Gweru on the Great Dyke, will encompass the development of a mine and concentrator capable of producing 58,000 oz of refined platinum at full capacity but first production is not expected until 2007.

PGM Supplies: Zimbabwe & Others
'000 oz

	2002	2003
Platinum	150	225
Palladium	170	250
Rhodium	10	15

Platinum

Use of platinum in medical applications such as pacemakers expanded by 8 per cent in 2003.

Purchases of platinum by Chinese jewellery manufacturers dropped to 1.2 million oz in 2003, after almost a decade of rapid and uninterrupted growth.

Platinum

Autocatalyst

Purchases of platinum for use in autocatalysts surged by an impressive 600,000 oz in 2003 to 3.19 million oz, a year-on-year increase of 23 per cent. A jump in purchases of platinum by North American auto makers was responsible for approximately half of this growth. In 2002 US-based car companies used a significant volume of platinum from inventories but by 2003 stocks had been largely depleted and purchases of platinum climbed to more closely reflect its underlying use.

In Europe, another strong year of diesel car sales coupled with the pending tightening of emissions regulations helped to push autocatalyst platinum demand up by 11 per cent. The retrofitting of catalysts and particulate filters to heavy-duty diesel trucks boosted Japanese purchases of the metal, whilst rapid growth in light vehicle sales in China and India raised demand in the Rest of the World.

Europe

In 2003 purchases of platinum by auto makers in Europe rose by 11 per cent to 1.34 million oz. Several factors contributed to the growth: strongly rising diesel car sales, tightening emissions legislation, and changes to the overall ratio of pgm use.

Consumer demand for diesel powered cars in Europe continued to grow at a tremendous rate in 2003. Sales of diesel cars increased by more than 5 per cent, reaching 6.15 million vehicles, equivalent to more than 43 per cent of total new car registrations.

The impact of rising diesel car sales on platinum demand was compounded by the imminent introduction of the next round of European emissions legislation: Euro IV standards. These will apply to 2005 vehicle models onwards (both gasoline and diesel) and mandate very substantial cuts in emissions of all pollutants but particularly NOx, and additionally for diesels, particulate matter.

In 2003 many Euro IV compliant models were already available and the catalysts on some of these contained higher pgm loadings to meet the tougher standards. This was particularly true of the diesel sector. One strategy for achieving the new limits on NOx is to reduce diesel engine combustion temperatures (the formation of NOx being highly temperature dependent). This, however, results in greater levels of CO being generated, which in turn can be managed by raising catalyst platinum loadings.

As elsewhere, European auto manufacturers have re-examined their current and likely future pgm use in light of the large premium that has evolved between the price of platinum and that of palladium over the last two years. Demand for pgm in 2003, however, was still being influenced by decisions to favour the use of platinum in gasoline autocatalysts that were made in 2000 and 2001 when the price of palladium spiked. Consequently, a proportion of the increase in platinum demand in 2003 was due to greater use of platinum-based catalysts rather than palladium-rich formulations on certain new vehicle models.

Japan

The Japanese vehicle industry purchased 510,000 oz of platinum in 2003, a jump of 80,000 oz (more than 18 per cent) compared with the previous year. Much of this surge in platinum demand occurred because of the introduction of legislation to control particulate matter emissions from heavy-duty diesel vehicles operating in the Tokyo metropolitan area. The regulation set tough new limits for particulate matter emissions for all heavy-duty trucks and buses. In essence, existing vehicles that did not meet the standards had to be fitted with either an oxidation catalyst or a diesel particulate filter (DPF), or had to be scrapped or sold outside Tokyo. Several neighbouring prefectures also introduced heavy-duty diesel retrofit rules based on the Tokyo example.

The Tokyo legislation applied from October 2003 and caused a rush to retrofit oxidation catalysts and DPF. A resulting shortage in the supply of catalyst substrates meant that the deadline for compliance was subsequently extended to January 2004. There was also a sharp increase in purchases of new, cleaner trucks as owners replaced ageing vehicles.

Short-term national regulations reducing particulate matter emissions from large trucks (over 12 tonnes) are due to come into effect in the autumn of 2004. These will be followed by tighter emissions regulations for all vehicles in 2005, including very stringent particulate matter and NOx limits for heavy-duty diesels. These have already led to the launch of new truck models fitted with oxidation catalysts and/or DPF.

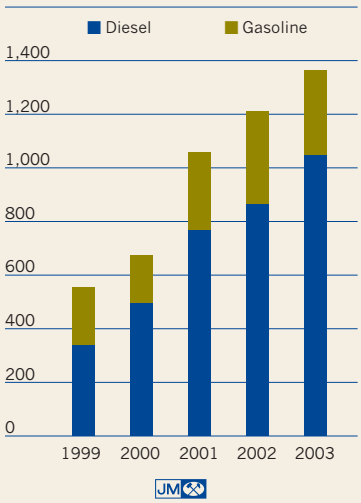
Against these positive trends for platinum consumption, the 1 per cent fall in car production in Japan in 2003 had little impact.

Platinum Demand: Autocatalyst
'000 oz

	2002	2003
Europe	1,210	1,340
Japan	430	510
North America	570	880
Rest of the World	380	460
Total	**2,590**	**3,190**

JM

European Demand for Platinum in Autocatalysts 1999-2003
'000 oz



JM

Surging sales of new cars in China helped to push up autocatalyst platinum demand by 21 per cent in the Rest of the World region in 2003.

North America

Purchases of platinum by the US auto industry surged by 54 per cent in 2003 to 880,000 oz, up from 570,000 oz the year before. A large proportion of this increase was due to the fact that US auto makers used quite substantial volumes of platinum from stocks in lieu of purchases in 2002 but, with inventories depleted, returned to the market for almost all of their metal requirements in 2003. Consequently, demand for platinum jumped.

Light vehicle sales in the USA surpassed most analysts' expectations in 2003, reaching 16.7 million units, a drop of less than 1 per cent compared with 2002. Importantly, however, sales of light trucks, notably sports utility vehicles, climbed by more than 3 per cent to almost 8.9 million as they continued to take market share from passenger cars. Light trucks now account for almost 54 per cent of all light vehicle sales in the USA. Because of their larger engine sizes light trucks generally require catalysts with larger volumes or higher pgm loadings than do cars.

Use of platinum-based catalyst systems also increased in the USA in 2003 as new vehicle models were launched, reflecting decisions on pgm use that were made when palladium was trading at a hefty premium to platinum. Naturally, given the reversal in the price relationship between the two metals, US auto makers are now seeking to migrate an increasing proportion of their future vehicle models to palladium-based catalysts.

It should be emphasised, however, that the big three US-based auto makers do not have a uniform approach to catalyst development and pgm use. There are also considerable differences in strategy between the US auto companies and their overseas competitors that operate vehicle manufacturing plants in North America. There has not, therefore, been a universal swing in favour of using palladium-based catalysts at the expense of platinum across all manufacturers and vehicle models.

The position is further complicated by the phase in of Tier 2 (federal) and LEV 2 (California) emissions regulations, which begins in 2004. These require a reduction in NOx emissions of around 75 per cent compared to existing limits, as well as cuts in hydrocarbon (HC) emissions. In some instances this led to an increase in catalyst platinum loadings in 2003 as car companies launched Tier 2 compliant vehicle models ahead of the regulations.

Finally, US demand for platinum in autocatalysts was given a small boost in 2003 by the retrofitting of emission control equipment to heavy-duty diesel trucks and buses under a programme promoted by the Environmental Protection Agency (EPA).

Rest of the World

Platinum demand in the Rest of the World grew by a rousing 21 per cent or 80,000 oz to 460,000 oz in 2003. The single largest component of this growth was the phenomenal expansion of the Chinese car market. Sales of passenger cars soared to exceed 2 million vehicles, whilst the volume of cars manufactured in the country jumped to 2.07 million – an increase on 2002 of 72 per cent. The leap in new car sales was facilitated by a combination of rising incomes and easier access to credit.

The tightening of regulations covering car emissions continued to progress in China last year, which is following the European framework regarding vehicle emissions. Euro II standards were introduced in Beijing and Shanghai during the first quarter of 2003 and will be enforced nationwide from July 2004. Because of tax incentives, however, many vehicles sold outside the two largest cities in 2003 were already Euro II compliant. The more stringent Euro III emissions limits are expected to be introduced in Beijing and Shanghai in 2005, with the rest of the country following suit in 2008.

Indian vehicle production also grew strongly in 2003, light vehicle output rising by almost 19 per cent

to just under 1 million cars and light trucks. Emissions regulations equivalent to Euro II have been introduced in several regions and will apply across the country from April 2005. Good growth in light vehicle production was also seen elsewhere in Asia (notably Thailand) as well as in Australia. Production in Brazil and Argentina edged higher but output in Mexico dropped by 14 per cent due to weaker domestic demand and lower exports to the USA.

Autocatalyst Recovery

Recovery of platinum from recycled autocatalysts increased by 14 per cent to an estimated 645,000 oz in 2003. Improvements in catalyst collection and recovery rates were seen in all regions, stimulated in part by the rising platinum price. Collection rates have also been rising as competition in the sector has become more intense, with several primary pgm smelters now utilising scrapped catalyst feedstock to supplement mine concentrate feed in order to maximise smelter throughput and efficiencies.

The fastest growth in the rate of recovery occurred in Europe, where cars fitted with catalysts accounted for a higher share of all scrapped vehicles. In addition, a greater emphasis has been placed on recycling of vehicles because of the European End of Life Vehicle legislation that comes into effect in 2005. The amount of platinum recovered from cars scrapped in Europe is estimated to have reached 110,000 oz in 2003, up by 22 per cent.

In volume terms, however, the largest rise in recovery was in the USA, where the estimated recovery of platinum jumped by 45,000 oz to 425,000 oz. This reflected higher catalyst recovery rates due to the rising platinum price and a change in the mix of pgm contained in scrapped catalysts. Recovery also increased in Japan and the Rest of the World, but total collection volumes in these regions were much smaller at 60,000 oz and 50,000 oz respectively.

Jewellery

Purchases of platinum for jewellery fabrication in 2003 fell by 13 per cent to 2.44 million oz, down from 2.82 million oz the year before. The decline was due to a significant drop in purchases of metal by both the Chinese and Japanese jewellery industries. Chinese demand slid from 1.48 million oz in 2002 to 1.2 million oz in 2003 as the rising platinum price cut profit margins throughout the sector. In Japan, consumers increasingly turned to white gold in preference to more expensive platinum in the lower priced segments of the jewellery market. In addition, the volume of platinum recycled by the industry jumped, due in part to the bankruptcy of several manufacturers.

In Europe, sales of platinum jewellery continued to grow strongly in the UK but remained subdued elsewhere. In the USA, platinum jewellery lost ground at the lower-priced end of the market but retail sales improved in the high quality fashion and bridal sectors.

Europe

Demand for platinum from European jewellery manufacturers increased modestly in 2003, rising by 6 per cent overall to 170,000 oz, still some way below the peak of 190,000 oz in 2000. The outstanding performance again came from the UK jewellery market. The weight of platinum articles hallmarked in the UK in 2003 jumped by 30 per cent to nearly 83,000 oz, of which just over 17,000 oz were imported items. Platinum has rapidly gained market share in the UK bridal sector and the availability of non-bridal jewellery designs in platinum has also expanded.

Demand for platinum from German jewellery fabricators was weak in 2003, with export sales to countries such as the UK, the USA and Japan providing the only clear opportunities for growth for many companies. The German market for platinum jewellery remained depressed; platinum bridal jewellery held ground but sales in the fashion sectors continued to be pressured by competition from less expensive white metals including white gold, silver, and titanium.

The retail sales climate was similarly mixed for Italian jewellery manufacturers last year, many of which cited the rise and volatility of the platinum price as being problematic. As in Germany, sales of bridal rings provided a stable core of platinum demand but white gold and silver gained market share at the fashion end of the market. In addition, continuing efforts to make platinum products lighter to keep metal costs down affected demand. The Swiss jewellery industry reported a fall in sales of platinum watchcases in 2003 but an increase in sales of other platinum jewellery; consequently overall demand for the metal was little changed.

Platinum Demand: Autocatalyst Recovery
'000 oz

	2002	2003
Europe	(90)	(110)
Japan	(55)	(60)
North America	(380)	(425)
Rest of the World	(40)	(50)
Total	**(565)**	**(645)**

JM

Growth in demand for platinum from European jewellery manufacturers was largely driven by higher retail sales in the UK.

Japan

Japanese purchases of platinum for jewellery manufacture dropped by 15 per cent in 2003 to 665,000 oz, the lowest level since the mid-1980s. The Japanese market for precious metal jewellery as a whole (platinum, gold and white gold) contracted further in 2003, with consumers still cautious about buying non-essential items.

The effect of lower retail sales on purchases of platinum was compounded by a high rate of inventory recycling. Retailers, wholesalers and fabricators continued to minimise their stock levels, and the liquidation of inventories from companies that exited the jewellery business altogether also contributed a significant volume of metal to the overall jewellery supply chain.

The poor profitability of some jewellers was exacerbated by the rapid rise in the spot price of platinum. The retail end of the jewellery industry in Japan has tended to estimate future raw material costs once every six months and companies budget accordingly. This leads to cash flow problems when the price of metal increases more rapidly than predicted, as was the case in 2003.

Japanese retail sales of platinum jewellery fell by around 11 per cent last year, although platinum maintained its share of the shrinking market. Sales of bridal jewellery were affected by a decline in the number of couples getting married (a long-term demographic trend), as well as by a fall in the number of engagement rings purchased.

In the fashion side of the market, sales of platinum jewellery dropped as the price of platinum climbed from an average of ¥2,400 per gram in January to ¥2,800 in December. This made white gold more competitive and, in the lowest price bracket (under ¥50,000), silver jewellery increased in popularity. It is worth noting that retail sales of yellow gold items during the year slumped by 26 per cent – the preference for white precious metal jewellery remains strong in Japan.

The picture at the upper end of the non-bridal market was more positive, with retail sales of platinum jewellery actually increasing on an annual basis. Unfortunately for Japanese jewellery fabricators, however, overseas brands gained a larger share of the market. Japanese manufacturers hoping to increase export sales also had to battle against the rising strength of the yen.

Platinum Demand: Jewellery
'000 oz

	2002	2003
Europe	160	170
Japan	780	665
North America	310	310
Rest of the World		
China	1,480	1,200
Other	90	95
Total	**2,820**	**2,440**

JM

North America

Purchases of platinum by jewellery fabricators in North America were flat in 2003, remaining unchanged at 310,000 oz. Platinum has developed a strong position in the bridal market in the USA, and sales of platinum wedding bands improved year-on-year. Many fabricators selling to the higher priced segments of the fashion jewellery market also reported better sales in 2003 than the year before, with retailers enjoying a strong Christmas season.

The rise in the price of platinum, however, made it increasingly hard for fabricators to produce pieces that could be sold into the lower price brackets without reducing the weight of chains and pendants to unacceptably low levels. In addition, US manufacturers faced increased competition from imports from Europe and Asia – the net result being no discernable change in total purchases of platinum.

Rest of the World

Demand for platinum for jewellery manufacture in the Rest of the World region deteriorated in 2003, sliding by 17.5 per cent to 1.295 million oz. The drop was entirely attributable to a fall in purchases of metal by Chinese jewellery fabricators from the peak of 1.48 million oz in 2002 to 1.2 million oz last year.

The primary reason for the fall in purchases of metal was the rising platinum price, particularly the speed of the rallies seen in the first and final quarters of the year. Demand dropped noticeably during January and February as the spot price surged from $600 to $700. When the price dropped back to close to $600 in April, buying by Chinese manufacturers picked up again ahead of the Labour Day holiday in early May. The SARS outbreak then caused a temporary lull in the market but sales recovered strongly in the third quarter of the year in the run up to October's National Day holiday period. In the final quarter of the year, however, the rapid rally in the price from around $700 at the beginning of October to a peak of just over $840 in December again cut purchases of metal.

Although jewellery retailers in China began to react more rapidly to changes in the price of the metal in 2003, retail price increases still lagged well behind the rising spot price as competition between jewellery stores remained fierce. Over the year as a whole, the price paid by Chinese jewellery manufacturers for platinum increased by 27 per cent but retail prices for platinum jewellery increased by less than half that.

The result was a tightening squeeze on manufacturers' profit margins, which had typically fallen to less than 2.5 per cent by the end of the year.

The rising cost of metal also prompted many jewellery fabricators to defer metal purchases for as long as possible and led to a reduction in stocks held by manufacturers and wholesalers. A considerable number of the former switched a proportion of their production into higher-margin white gold jewellery.

The start of platinum trading on the Shanghai Gold Exchange (SGE) in August, however, was a positive development. It enabled manufacturers to source metal more easily and reduced the effective rate of VAT on platinum purchased through the exchange from 17 per cent to zero. At the same time, the 10 per cent consumption tax on platinum jewellery was cut to 5 per cent and the tax burden was shifted from manufacturers to retailers. From the start of platinum trading on the SGE on the 13th August through to the end of December a total of 246,000 oz of metal was bought through the exchange.

Estimated retail sales of platinum jewellery in China fell by around 10 per cent in volume terms as prices rose, with some erosion of market share by white gold. A lack of product choice and fresh designs as fabricators reduced their platinum ranges also had an impact. Nevertheless, for the majority of the Chinese jewellery-buying public, platinum jewellery retained its strong allure.

Jewellery demand for platinum elsewhere increased moderately in 2003 as manufacturers in South East Asia gained an increased share of export markets, primarily the USA.

Chemical

Consumption of platinum in the chemicals industry slipped to 310,000 oz in 2003 after having posted a recent high of 325,000 oz the year before. Use of the metal in catalysts for bulk chemicals manufacture eased as less new capacity came on stream, whilst demand for platinum catalyst gauze from the nitric acid industry also softened.

The use of platinum in process catalyst applications is greatest in the silicones industry, as losses of metal during operation are significant. Operating rates in the sector were broadly stable in 2003 and there were no significant additions to silicones manufacturing capacity. However, silicones producers and catalyst manufacturers have had some success in thrifting the platinum content of catalysts and demand for the metal fell moderately as a result.

In another major process catalyst application for platinum, the manufacture of paraxylene, demand also slipped in 2003 compared with 2002. In this sector the construction of new capacity is the main driver of catalyst demand; metal losses during the paraxylene manufacturing process are low.

Metal purchases and catalyst production generally occur well in advance of the commissioning of plant expansions. Demand for platinum in 2002 grew strongly as catalysts were manufactured to meet the significant volume of additional capacity (equivalent to around 9 per cent of the global total) that subsequently came on stream in 2003. Demand for platinum-based catalysts in 2003, however, fell back, a reflection of the fact that less additional capacity is due to be commissioned in 2004.

Orders for platinum gauze from the global nitric acid industry weakened somewhat in 2003. Nitric acid manufacturers faced high and volatile natural gas prices during the first half of the year, which had a detrimental effect on the profitability of the sector and resulted in some capacity being idled, notably in North America. By the end of the year, however, gas prices had fallen back and the supply/demand balance had tightened, raising profitability throughout the entire nitrogen industry. Demand for nitric acid is heavily dependent on the nitrogen fertiliser market, which continues to show good growth globally, particularly in Asia.

Platinum Demand: Chemical
'000 oz

	2002	2003
Europe	115	105
Japan	30	40
North America	100	90
Rest of the World	80	75
Total	**325**	310

JM

Electrical

Demand for platinum used in electrical applications grew by 8 per cent in 2003, rising to 340,000 oz. Shipments of hard disks increased rapidly during the year as orders for computers and other electronic goods rebounded following two years of weak sales. Demand for platinum used in thermocouples also grew in line with higher steel and semiconductor output.

Platinum is an essential component of the magnetic alloys used in computer hard disks. Hard disk shipments rose substantially in 2003 as both corporate and consumer purchases of computing equipment rebounded from the downturn of 2001 and 2002. Sales of non-computer consumer electronics containing hard disks (such as digital video recorders and

Platinum Demand: Electrical
'000 oz

	2002	2003
Europe	40	45
Japan	55	60
North America	100	100
Rest of the World	120	135
Total	**315**	**340**

JM

Platinum Demand: Glass
'000 oz

	2002	2003
Europe	10	10
Japan	60	50
North America	30	(5)
Rest of the World	135	120
Total	**235**	**175**

Platinum Demand: Petroleum Refining
'000 oz

	2002	2003
Europe	15	15
Japan	5	5
North America	45	45
Rest of the World	65	85
Total	**130**	**150**

personal music players) also increased. In addition, as manufacturers continued to develop disks with higher data storage capacities, the average platinum content per disk rose. Increased demand was offset to some extent by the continuing fall in the disk to drive ratio.

Strong growth in crude steel production in 2003 was seen in Asia (notably China and India) and South America (mainly Brazil). This far outweighed a slight fall in US output and only sluggish growth in Western Europe. Rising steel production and investments in new capacity had a knock-on effect on demand for high temperature thermocouples, which typically contain platinum wire.

The manufacture of semiconductor wafers is another leading application for platinum-based thermocouples. Shipments of semiconductors began to recover rapidly during the latter part of 2003, feeding through to an upturn in thermocouple demand.

Demand for platinum used in fuel cell development programmes expanded in 2003, although the volumes concerned remained small and numerous hurdles to mass production of fuel cell powered products remain. There was a more intensive focus on the development of safe and efficient infrastructure for refuelling fuel cell vehicles with hydrogen, as opposed to on-board reforming systems; whilst the portable market saw the launch of several new prototype fuel cell powered laptop computers.

Glass

Glass industry demand for platinum dropped sharply in 2003, partly because the pace of investment in new capacity slowed but also in reaction to the rapidly rising price of the metal. Net purchases of platinum by glass manufacturers dropped by 26 per cent to 175,000 oz – the lowest level since 1994. Glass producers sought to minimise their platinum usage and a considerable volume of metal was sold back to the market.

The surge in the price of platinum from $600 at the start of 2003 to over $840 in December had a significant impact on purchases of metal by the global glass industry. Glass manufacturers sought to manage their inventories of platinum articles more efficiently, made efforts to thrift platinum use, worked to extend the lifespan of existing platinum equipment, and deferred purchases of new products containing platinum for as long as possible.

The emphasis on improved housekeeping of metal, coupled with the closure of several glass furnaces worldwide, resulted in the sale of a significant volume of metal back to the market, notably in North America.

The effects of the above on platinum demand outweighed further expansions in Asia of glass fibre manufacturing capacity and plants producing high quality glass for flat panel displays. Considerable investment continued to be made in new plants, particularly in China, but the rate of expansion in the region slowed compared with 2002.

The net effect was that demand for platinum in glass manufacturing applications dropped by 26 per cent year-on-year to 175,000 oz.

Petroleum Refining

Demand for platinum used in petroleum refining catalysts increased by 15 per cent in 2003 to 150,000 oz as investment was made in new capacity in the Middle East and South America. With demand for many bulk petrochemicals increasing, some reforming and isomerisation capacity that had been taken off line the previous year was also brought back into service.

Platinum-based catalysts are used in reforming and isomerisation processes in the refining of crude oil. The volume of new catalyst required to top up existing installations is relatively stable, with fluctuations in demand largely related to the construction of new refining capacity. In 2003, investment was made in new petroleum reforming and isomerisation plants in the Middle East, Libya and South America, stimulating demand for platinum-based catalysts.

Little change in demand for platinum catalysts was seen in the mature petroleum refining industries of North America and Western Europe, although some capacity in the latter that had been mothballed in 2002 was brought back into production last year.

Other

Total demand for platinum from all other applications increased marginally in 2003 to 545,000 oz. Within this category, a drop in demand for platinum used in dental alloys and automotive applications (spark plugs and oxygen sensors) was offset by greater use of the metal in turbine blades and in the biomedical market.

The consumption of platinum in dental alloys (in which it is alloyed with gold) softened slightly in

Western Europe, North America and Japan. Changes to the mix of metal alloys used and greater use of porcelain dental products accounted for the decline. The rising price of both gold and platinum increased substantially the cost of high-gold alloys (which typically contain 8 to 15 per cent platinum). This, coupled with a simultaneous drop in the cost of palladium-based alloys, resulted in demand for high-gold alloys weakening.

Sales of high-performance platinum-tipped spark plugs to auto companies edged down in 2003 in line with lower vehicle production in North America, by far the largest market for platinum spark plugs. In the Japanese market demand was broadly flat, and whilst platinum spark plugs continued to slowly gain market share in Europe, the impact on metal demand was negligible.

In the automotive sector, platinum is also a key component of oxygen sensors, which in turn are essential to modern emissions control systems. The number of oxygen sensors used per vehicle has stabilised over the last two years, following a rise between 1999 and 2001 that was connected with the introduction of Euro III emissions legislation. Demand in 2003, therefore, was closely linked to light vehicle output, and consequently fell by 3 to 4 per cent in North America and was little changed in Western Europe and Japan.

The use of platinum in biomedical equipment and oncological drugs continued to expand in 2003, continuing a decade-long trend. The USA dominates demand for medical equipment containing platinum components (such as pacemakers, stents, and catheter guide wires) and consumption of platinum in these applications climbed by an estimated 8 per cent in North America last year.

The USA is also the largest centre for the manufacture of the platinum-based family of anti-cancer drugs, although they are also produced in Europe, Japan and elsewhere. Global use of platinum in the production of anti-cancer drugs rose by an estimated 9 per cent in 2003.

Turbine blades coated with a thin layer of platinum have improved resistance to the high temperatures and severe operating conditions in jet engines. Demand for the metal in this application increased significantly last year as the global aircraft manufacturing industry saw a sharp upturn in orders following a slump in 2002.

Investment

Net purchases of platinum bars and coins by investors in 2003 fell as higher prices stimulated increased sales of products back to dealers in Japan and reduced purchases of bullion coins in the USA. Overall, net investment demand for platinum fell to just 15,000 oz, down from 80,000 oz in 2002.

Demand for the US Mint's Platinum Eagle bullion coins dropped to just over 24,000 oz in 2003, a fall of 22 per cent from the 30,800 oz sold the previous year. The marked increase in the price of platinum deterred many purchasers but, somewhat perversely, sales of Platinum Eagle bullion coins during the second half of the year were considerably above sales in the first half, despite the average price of platinum being much higher. It appeared that some investors were encouraged to buy into all precious metals as their prices rallied, partly in response to increasing mainstream media coverage of the sector. Sales of Platinum Eagle proof coins to collectors remained broadly flat in volume terms in 2003.

In Japan, the sale of large investment bars back to dealers was also strongly influenced by the rising price of platinum and outweighed new purchases by 15,000 oz over the course of the year. The local price in yen climbed from an average of around ¥2,400 per gram in January to ¥2,600 in February and March, stimulating a sharp rise in disinvestment and a slowing of purchases of new bars both directly from dealers and under Personal Accumulation Plans.

The rate of sales back to the market slowed during late March and April as the platinum price dropped back below ¥2,400, and remained fairly stable through to the end of June. The following month the rate of divestment increased once more as the price again climbed above ¥2,600, outweighing new purchases of investment bars.

From September through to the end of November, sales back to the market subsided again – although the US$ spot price of platinum made significant gains, the simultaneous appreciation of the yen kept the local price more or less in check. In December, however, the sharp rally in the spot price from around $770 to over $840 was reflected in the yen price, which climbed from approximately ¥2,700 at the start of the month to over ¥2,900 at its peak. Consequently, disinvestment accelerated in Japan, exceeding purchases of new bars by a considerable margin.

Platinum Demand: Other
'000 oz

	2002	2003
Europe	190	195
Japan	55	55
North America	265	265
Rest of the World	30	30
Total	**540**	**545**

Platinum Demand: Investment
'000 oz

	2002	2003
Coins and small bars		
Europe	0	0
Japan	5	5
North America	40	25
Rest of the World	0	0
	45	**30**
Large bars in Japan	**35**	**(15)**
Total	**80**	**15**

30 Years in the Development of Autocatalysts

When the first car to be fitted with a catalytic converter rolled off a production line in the USA in 1974, it was a huge landmark for both the platinum group metals markets and the global auto industry. Over the 30 years since then, the automobile catalytic converter has been responsible for tremendous improvements in air quality and for shaping much of the pgm industry as it stands today.

This article traces some of the milestones in the development of environmental legislation and the catalytic converter, from the smogs of California in the 1950s through to the present day.

California in the 1950s and 1960s – "and the sky is grey... "

Emissions from motor vehicles had been recognised as a potential environmental problem in the USA from as early as the 1950s, when photochemical smog (with its characteristic grey-brown haze) was becoming a persistent feature of the Los Angeles basin in California. Tokyo and other large metropolitan areas also later suffered from similar pollution problems.

Research in California showed that the process of smog formation was complex but that it involved nitrogen oxides (NOx) and hydrocarbons (HC) reacting in sunlight to produce ozone. As air quality deteriorated, politicians began to take note of the issue and in 1963 the US Clean Air Act was passed. This first attempt to control atmospheric pollution in the USA set standards for stationary source emissions, such as those from power plants and factories. However, measurements showed that automobiles were responsible for 70 per cent of the HC emissions and 60 per cent of the NOx emissions in the air. Consequently, the Clean Air Act amendments of 1965 (the US Motor Vehicle Air Pollution Control Act) were adopted and set the first federal emission standards to control pollution from automobiles, beginning with 1968 models. The standards set were a 72 per cent reduction in HC and a 57 per cent reduction in CO from 1963 levels and were to be effective for 12,000 miles using fuel containing 3 grams of lead per gallon.

The Pollutants and Chemistry of Emission Control

The main pollutants from vehicle exhausts are hydrocarbons (HC), formed by the incomplete combustion of the fuel and encompassing a wide range of organic compounds such as methane, aromatics, oxygenates, etc; carbon monoxide (CO); and oxides of nitrogen (NOx). Carbon dioxide and water are also emitted and, particularly in the early years, lead, sulphur and phosphorus compounds were present.

In simple terms the reactions that occur within a three-way catalytic converter are the oxidation of carbon monoxide to produce carbon dioxide:

$$2CO + O_2 \rightarrow 2CO_2$$

the reaction of hydrocarbons with oxygen to produce carbon dioxide and water:

$$HC + O_2 \rightarrow CO_2 + H_2O$$

and the conversion of nitrogen oxides to nitrogen via reduction reactions with carbon monoxide and hydrocarbons:

$$2NO + 2CO \rightarrow 2CO_2 + N_2$$

$$NO + HC \rightarrow CO_2 + H_2O + N_2$$

Several catalyst systems from US manufacturers were selected for evaluation but their durability was severely limited by the high lead content of the fuel, which acted to rapidly deactivate (poison) the catalyst. Furthermore, the car industry was not enthusiastic about fitting 'add on' devices manufactured by others, and through the use of engine modifications auto makers were able to meet the required standards without the use of catalysts. However, the driveability and fuel economy of US cars with such engine modifications were poor by any criteria and the air quality, particularly in California, continued to deteriorate as the number of cars on the road increased.

Concern for the environment amongst the general public (and

1950's ...

■ *Work by Dr. Arie Haagen-Smit at the California Institute of Technology proved that automotive exhaust emissions were a major source of photochemical smog in Los Angeles.*

1965 ...

■ *The US Motor Vehicle Air Pollution Control Act (amendments of the Clean Air Act) set the first federal emission standards to control pollution from automobiles, beginning with 1968 models. The targets were met without catalysts.*

1970 ...

■ *An estimated 20 million people participate in 'Earth Day' events in the USA. Subsequently, the US Environmental Protection Agency (EPA) is established and US Congress passes a major revision of the Clean Air Act (1970 amendments) incorporating substantially lower vehicle emissions limits. Agreement to phase out lead in gasoline in the USA from 1972 onwards.*

1971 ...

■ *Johnson Matthey files a patent covering the use of a rhodium-promoted platinum catalyst to control NOx and gaseous organic compounds.*

enlightened politicians) in the USA increased throughout the late 1960s, culminating in Earth Day in April 1970. This event contributed directly to the passing of the 1970 Amendments to the US Clean Air Act by the US Congress and to the establishment of the US Environmental Protection Agency (EPA) a few months later.

The 1970 Clean Air Act amendments required car emissions of HC, CO and NOx to be reduced by at least 90 per cent from 1970/71 levels by 1975/76. It appeared that engine modifications alone would be unlikely to meet these much tougher standards and so a real opportunity emerged for the introduction of catalysts on cars.

1970s – Rapid progress in catalyst development

The 1970 US Clean Air Act legislated for control of all three major pollutants but catalysts were only required to control HC and CO – it would be some years before catalytic control of NOx would become necessary. Nevertheless, the obstacles to developing a successful oxidation catalyst that could operate in an engine exhaust system were considerable, and were compounded by the fact that car manufacturers were adamant that no significant engine modifications would be made to overcome catalyst limitations.

The relative cost of pgm caused many car companies to initially favour catalysts formulated with base metal compounds such as copper chromite. However, a major problem for catalyst engineers was the high emissions that occur when a car is started from cold; the catalyst needs to reach its operating or 'light-off' temperature before it starts to work. Compared with platinum-based catalysts, base metal formulations performed poorly, requiring higher light-off temperatures and so taking longer to start converting pollutants effectively. In addition to their inferior catalytic activity, base metal catalysts were also highly susceptible to poisoning by sulphur present in the fuel and were unable to meet the required durability criteria. Although pgm can also be poisoned by sulphur, the effects are much more subtle and less problematic.

The Mark 1 Volkswagen Golf, launched in the USA in 1974 as the 'Rabbit', was one of the first mass produced cars to be fitted with a catalytic converter.

With experimental work focussed on pgm catalysts, researchers then discovered that the concept of promoting platinum with other metals could produce catalysts with superior light-off performance to platinum-only catalysts. The most effective promoters were found to be other platinum group metals, and platinum-rhodium and platinum-palladium catalysts became the frontrunners in the race to meet the US regulations.

Catalysts confirmed as the solution to pollution

Although the North American car industry was not enthusiastic about the proposed Clean Air Act legislation, vehicle manufacturers were required by the EPA to demonstrate that they had made a determined effort to meet the 1975/76 standards. In 1972 the EPA held the first of several hearings to assess progress to which the public and media were invited.

At the hearings, some vehicle manufacturers voiced doubts that the emissions limits could be met. However, Johnson Matthey had

1972 ···

■ *Corning develops cordierite ceramics with high temperature and thermal shock resistance for catalyst monoliths. Johnson Matthey proves to the EPA that the US emissions regulations can be met using rhodium-platinum catalysts.*

1974 ···

■ *Effect of Middle Eastern oil embargo intensifies; US Congress sets the first fuel economy goals for automobiles, starting with 1975 models. The first catalyst substrates, with 200 cells per square inch (cpsi) and walls of 0.3 mm thick, are shipped to autocatalyst manufacturers.*

1975 ···

■ *The first cars fitted with oxidation catalysts reach showrooms in the USA; unleaded gasoline is widely available.*

1976 ···

■ *Japanese vehicle emissions standards to control HC, CO and NOx come into effect.*

1977 ···→

■ *US Clean Air Act amendments agreed to tighten emissions standards further from 1981 onwards.*

previously demonstrated to the EPA that vehicles fitted with a platinum-rhodium catalyst could successfully meet the required criteria. The EPA subsequently reaffirmed the timetable for the introduction of the standards, a ruling that was widely reported in the media at the time.

With the effectiveness of the catalyst proven in practice, work then began in earnest on developing a suitable support for the catalyst in the exhaust system and an economically viable production process. At the same time, research continued on further improvements to pgm catalyst technology.

Support from substrates

The successful introduction of auto catalysts was dependent on the development of a supporting material (or substrate) that could cope with the extremely demanding vehicle exhaust environment: the temperature can vary from ambient up to 1,000°C and can swing rapidly from one extreme to another; there are pulsations from the engine; the exhaust system vibrates; the gas mixture reaching the catalyst varies; and when catalysts were first introduced there was significant residual lead in fuel as well as high levels of sulphur and phosphorus compounds.

The major breakthrough came when Corning Inc. licensed extrusion technology from ICI and used it alongside technology involving a magnesium aluminium silicate ceramic known as cordierite ($Mg_2Al_4Si_5O_{18}$), which was known to have a very low coefficient of thermal expansion. This enabled the production of bricks or 'monoliths' with a honeycomb structure that had a sufficiently high melting point and the thermal durability to withstand the tough operating environment, and that were relatively inexpensive to produce. The early, extruded monoliths had channels, or 'cells', with a square cross section and were produced with cell densities of 100 or 200 cells per square inch (cpsi), with a wall thickness of 0.3mm.

There were strong indications that reactions in exhaust catalysts would be quickened by increasing the surface area of the monolithic supports. It was not long, therefore, before ceramic monoliths with 300 cpsi, 400 cpsi and even higher numbers of cells per square inch with thinner walls became available from both Corning and NGK of Japan, which had also entered the market. In the late 1970s, metallic substrates derived from ultra-thin foils also became available. These were manufactured from corrosion-resistant steel only 0.05mm thick, allowing high cell densities to be achieved.

Although the monoliths had high surface to volume ratios, their intrinsic surface area was still too low to enable the active catalytic metals to be adequately dispersed. It was therefore necessary to apply a coating to the cells to increase the surface area. After extensive test work on a number of materials, alumina proved to be the best choice due to its chemical and physical characteristics, widespread availability and relatively low cost.

The Evolution of Emissions Standards in the USA (grams pollutant per mile)

Vehicle model year	HC	CO	NO_x
Pre-Control	9.0	90.0	3.1
1975	1.5	15.0	3.1
1977	1.5	15.0	2.0
1981	0.41	3.4	1.0
1993 (California)	0.25	3.4	0.4
1994 US Tier 1	0.25	3.4	0.4
1994 TLEV	0.125	3.4	0.4
1997 TLEV	0.075	3.4	0.2
1997 – 2003 ULEV	0.04	1.7	0.2
2004 ULEV2	0.04	1.7	0.5
2004 – 2007 SULEV2/US Tier II	0.04	1.7	0.2

The ongoing tightening of emissions regulations continues to drive autocatalyst development and strongly influences pgm consumption.

Coating the monolith

Having identified the most suitable high surface area material, it was then essential to develop technology to apply this to the monolith. The overall principle was to make a slurry of alumina in water, apply it to the monolith as a 'washcoat', and then dry and

LATE 1970's

■ *Ceramic monolith cell density improved to 400 cpsi and cell wall thickness is reduced to 0.15 mm. Ultra-thin metal foil substrates introduced. Increased substrate surface area helps to improve the pollution conversion efficiency of catalysts.*

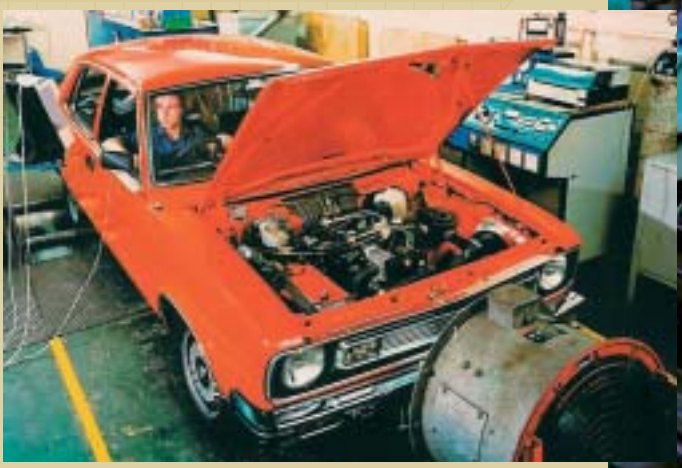
1981

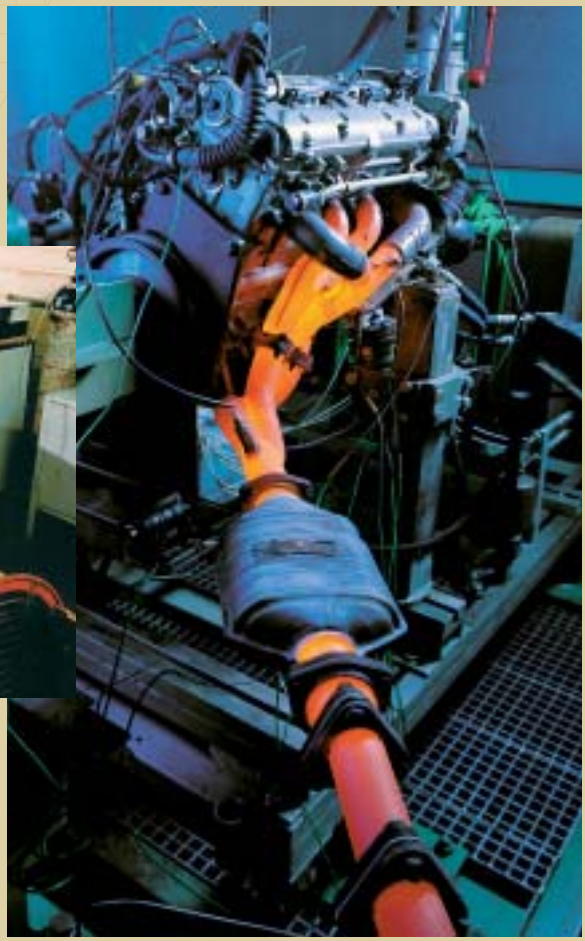
■ *To meet the strict NOx limits under the amended Clean Air Act, more sophisticated 'three-way' catalytic converters together with on-board diagnostic systems including oxygen sensors are introduced.*

EARLY 1980's

■ *Performance of three-way catalytic converters significantly enhanced by use of improved oxygen storage materials (based on cerium dioxide) in catalyst washcoats. Vehicle emissions regulations introduced in Australia and Germany.*

calcine the catalyst in order to fix the washcoat to the support. Applying washcoats throughout the narrow channels within the monoliths and then clearing the excess was a significant challenge; it was important to prevent too much narrowing of the channels or indeed complete blockage, whilst obtaining strong adhesion of the washcoat to the substrate.





Tests on a Chrysler Avenger in the early 1970s were instrumental in proving that catalytic converters could be effective and durable. The science of catalyst research and testing has come a long way in 30 years.

The next requirement was to add accurately controlled amounts and ratios of platinum group metals. Not surprisingly, researchers discovered that different metal preparations could give vastly different catalyst performance, depending upon the interaction with the support. Various proprietary techniques were adopted by different catalyst manufacturers to introduce accurate quantities of pgm to the substrate, all of which required sophisticated chemistry to control the properties of the coating during its application. High volume manufacturing processes were successfully developed and commercial production of catalysts began in 1974.

The catalyst for cleaner fuels

Sulphur poisoning was instrumental in the failure of base metal catalysts but was considered less important to the first precious metal catalysts. The more problematic poisons for precious metal catalysts were lead and phosphorus compounds in fuel. Catalyst resistance to both could be improved by adjusting washcoat formulations but for the catalytic converter to keep operating successfully over the required mileage the lead and phosphorus content of gasoline had to be reduced to trace levels. The EPA consequently instituted the first regulations for the effective phase out of lead and phosphorus additives in gasoline in 1973. At that time the average lead content in gasoline in the USA was 2 to 3 grams per gallon, resulting in around 200,000 tonnes of lead being emitted from vehicle exhausts every year. By 1996, when the sale

1990 ···

■ *Further amendments to Clean Air Act in the USA require greater reductions in HC, CO, NOx and particulate emissions from 1994 onwards (referred to as Tier I standards). Johnson Matthey files a patent covering the use of NO_2 to reduce the combustion temperature of diesel particulate matter in a filter, a system subsequently commercialised as the Continuously Regenerating Trap™.*

1991 ···

■ *New legislation introduced in Japan sets much more stringent vehicle NOx emissions limits.*

1993 ···

■ *European Union emissions regulations that necessitate the use of catalytic converters (Euro 1) come into effect.*

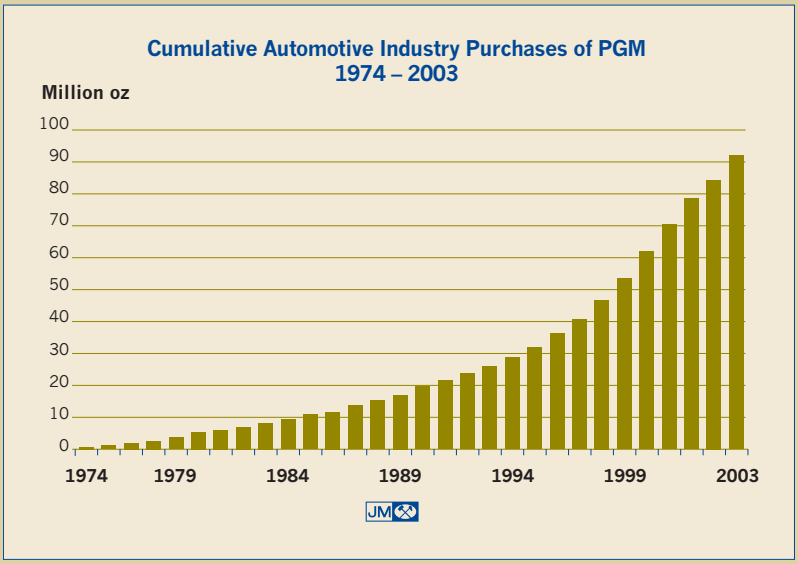
1994 ·····→

■ *Phase in of Tier I emissions standards begins in the USA.*

of leaded fuel for on-road vehicles was eliminated completely, emissions of lead had dropped to less than 2,000 tonnes per year – a direct beneficial consequence of the introduction of catalytic converters.

With the introduction of increasingly tighter emissions regulations, attention later switched to the sulphur content of fuels and its long-term deleterious effect on the efficiency of catalytic converters. The more recent introduction of clean-burning low and ultra-low sulphur fuels has been integral to advances in the performance of automobile catalysts, and will be crucial to achieving substantial cuts in the emissions of particulate matter from diesel powered vehicles in future.

During its first 30 years the autocatalyst industry consumed over 90 million oz of pgm.



Disproving the scare stories

During the early days of vehicle emission control, there was some opposition to the introduction of catalysts, both on the part of the auto industry and the public. There was a perception that catalysts imposed significant back-pressure on vehicle exhaust systems and caused poorer performance and fuel economy. What was often overlooked was that, before catalysts, engine modifications were the only way to meet emissions legislation and it was these that often reduced performance.

A number of scare stories arose around exhaust catalysts and each of these had to be treated seriously. Catalysts were accused of starting forest fires and emitting cyanide, sulphuric acid and precious metal particles, amongst other things. Whilst some of these claims (cyanide emissions for example) were readily disproved, others such as sulphuric acid emissions required significant work in order to prove that the fears were groundless.

Tightening regulations push catalyst development

From the mid-1970s onwards the tightening of auto emissions regulations stimulated major advances in catalyst design. With air pollution in Tokyo reaching uncomfortable levels, tough exhaust emission regulations were introduced by the Japanese government and came into effect on 1976 vehicle models. The following year, further amendments to the US Clean Air Act (to be applied from 1981 vehicle models onwards) tightened the standards for HC and CO emissions and, most significantly, included tough new targets for emissions of NOx. Work on developing catalysts that could simultaneously oxidise CO and HC to carbon dioxide and water while also reducing NOx to nitrogen ('three-way' catalytic converters) accelerated as a result.

One of the keys to the successful commercial introduction of three-way catalysts in 1981 was the development of the oxygen sensor. The ability of three-way catalysts to deal effectively with CO, HC and NOx is heavily dependent on the ratio of air to fuel in the engine being maintained at an optimum balance for the conversion of all three pollutants. The introduction of oxygen sensors enabled engineers to design closed-loop engine management systems that could precisely monitor and control the mixture of air and fuel.

Further advances were made with the advent of oxygen storage materials, which were incorporated into the catalyst washcoat. Under rich conditions (excess fuel) these materials release oxygen to facilitate the oxidation of CO and HC. Under lean conditions (excess air) they enable NOx reduction by storing oxygen. Cerium dioxide was found to be a highly effective oxygen storage material and also promoted much

1996 ···

■ *European Union emissions regulations tighten as Euro 2 standards are applied. Californian Low Emission Vehicle (LEV) standards come into force, emphasising the cold-start control of emissions; palladium-based catalysts found to be particularly suited to controlling HC emissions on engine start-up.*

1998 ···

■ *Ceramic substrates of 600 cpsi introduced, wall thickness reduced to 0.075 mm.*

1999 ···

■ *National Low Emissions Vehicle (NLEV) emissions standards take effect in the USA, requiring very substantial reductions in NOx.*

2000 ···

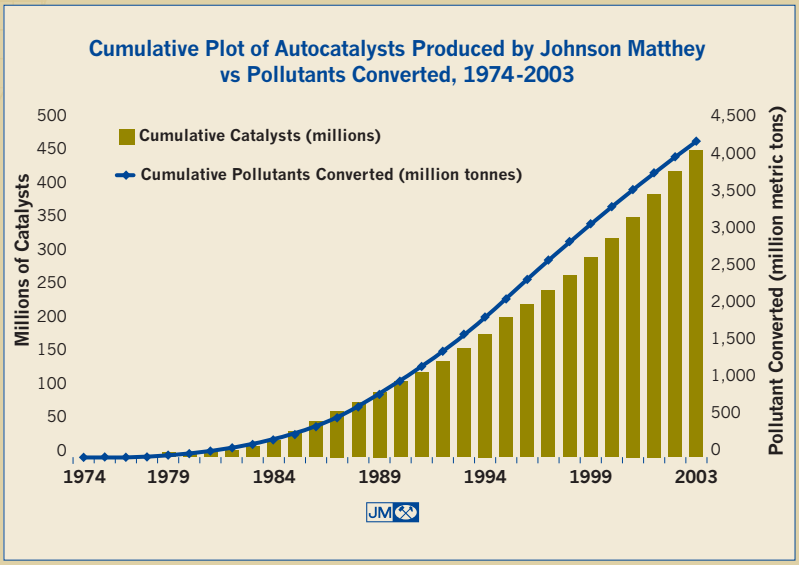
■ *Catalyst substrates with 900 cpsi and ultra-thin walls of 0.05 mm enter production for 2001 model year vehicles. Metal foil substrates available at up to 1,000 cpsi and with 0.025 mm thick walls. EU emissions standards for all road vehicles become more stringent with introduction of Euro 3 regulations.*

Autocatalysts

higher catalytic activity for the conversion of CO and NOx.

Research and development of improved catalytic converters progressed throughout the 1980s and early 1990s as emissions control legislation continued to tighten in the USA and spread to countries such as Germany and Australia. Assisted by the sophisticated surface analysis technique of X-ray photoelectron spectroscopy, the industry began to gain a deeper understanding of what happens to multi-metal catalyst in use. In particular, this work raised the question of whether the physical separation of platinum and rhodium within a catalyst would improve its performance.

Trials showed that catalysts in which the two metals had been deliberately separated from each other resulted in lower emissions. This led to the design of catalysts in which the distribution of pgm within the structure of the catalytic layer was closely controlled. The first of these structural catalysts came into use in the early 1990s and, through their improved thermal stability and more rapid light-off, helped to significantly improve catalyst performance.



Coming up to date

The control of vehicle emissions became increasingly widespread during the 1990s as regulations that necessitated the fitment of catalytic converters were introduced in the European Union, Mexico, Brazil, India, Malaysia and Thailand. Existing regulations in the USA and Japan also became progressively more stringent and substantial reductions in particulate matter emissions were increasingly mandated. These factors, together with the constant pressure from auto makers to minimise the cost of emissions control systems, were and are the driving forces behind catalyst development.

Today it is possible to produce catalysts on ceramic substrates with as many as 900 cells per square inch and walls less than 0.05mm thick, whilst metallic substrates of 1,000 cpsi and walls of only 0.025mm thick are available and offer the ability to produce complex internal structures. Catalysts with exceptional thermal durability can now be mounted very close to the engine manifold, whilst the control of pgm distribution on the catalyst has become even more sophisticated. Advances such as these have allowed engineers to keep abreast of ever tightening emissions legislation through improving catalyst performance whilst at the same time also enabling significant reductions in average pgm loadings.

Johnson Matthey has produced over 450 million autocatalysts since 1974, which have converted more than 4 billion tonnes of pollutants into harmless gases.

Conclusion

In 1960 a car would typically pump out over 100 grams of CO, HC and NOx for every mile driven. Today, a new car bought in the USA, Japan or Western Europe will only emit around 2 grams of these pollutants per mile. The ability to achieve exhaust emissions that are close to zero from today's cleanest cars is the result of more than three decades of research and development by automotive manufacturers, catalyst companies, and substrate suppliers in response to ever more demanding environmental legislation.

The permissible limits on auto emissions will continue to tighten over the next few years in already highly regulated markets such as the USA and Europe. In countries where car ownership is rapidly increasing, China and India for example, legislation is catching up quickly. In addition, emissions regulation of the heavy-duty diesel sector is set to become tougher and more widespread. These trends will drive even further enhancements in catalyst efficiency whilst providing new opportunities for the platinum group metals.

Acknowledgements
This article draws heavily on papers written by Dr. Barry Cooper, Dr. Gary Acres, and Dr. Brian Harrison of Johnson Matthey plc and particular thanks are due to them for their assistance and input.

2000-01 ...

■ *The palladium price spike peaks at $1,094 per oz.*

2003 ...

■ *Strict particulate matter limits introduced for heavy-duty diesel vehicles operating in the Tokyo area, requiring a substantial programme to retrofit catalysed particulate filters. Diesel car sales in Europe surpass 6 million vehicles for the first time.*

2004...

■ *Phase in of US Tier II emissions standards begins. These mandate further large reductions in NOx and particulate matter emissions. Tier II compliant vehicles are up to 99 per cent cleaner than vehicles sold in the 1960s.*

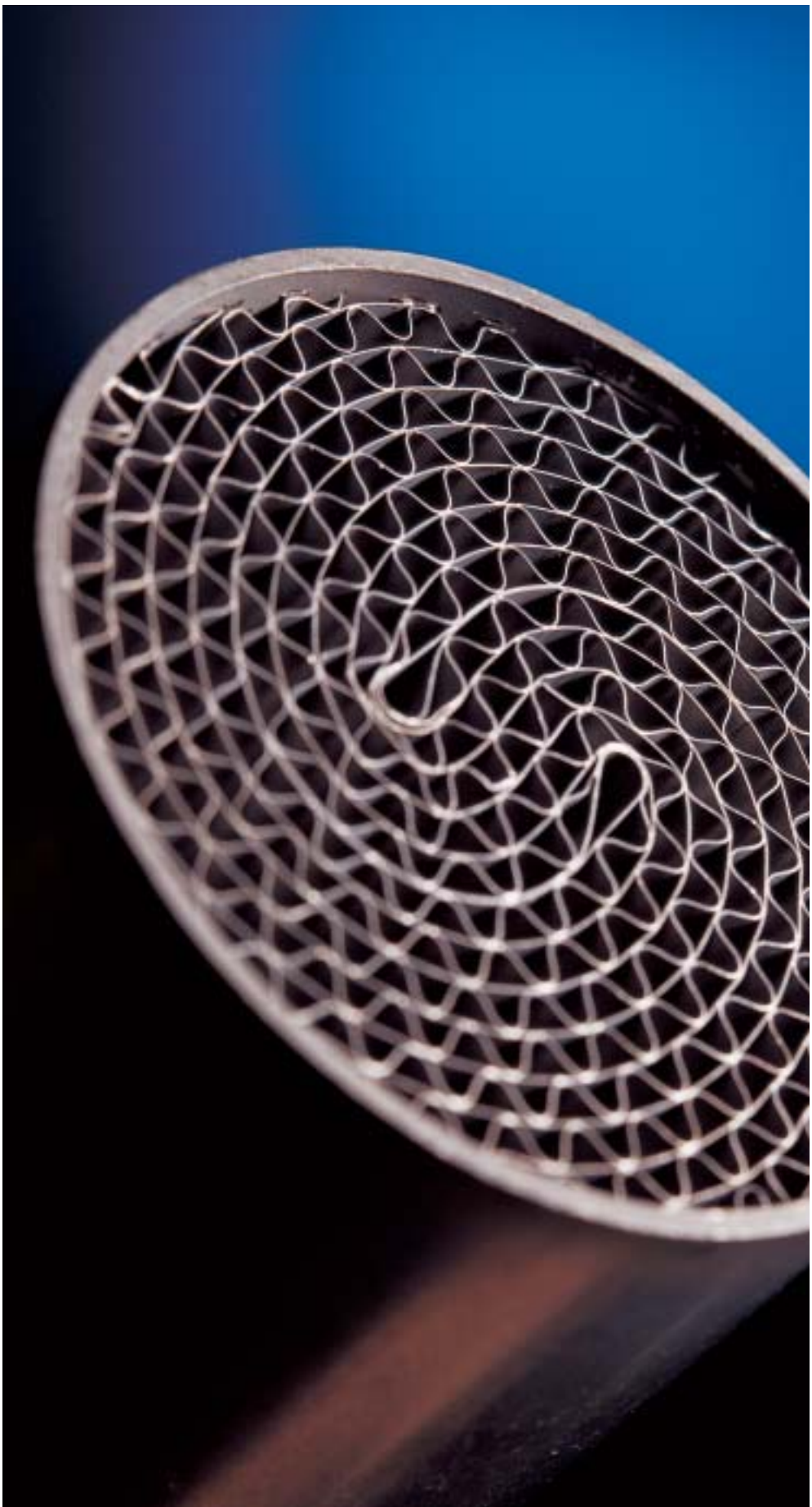
2005-08 ...

■ *Euro 4 emissions regulations and new Japanese standards will apply to new vehicle models and will require further substantial reductions in emissions of all major pollutants, particularly particulate matter from diesels. Phase in of US Tier II standards to be completed; Euro 5 standards likely to be finalised; regulation of vehicle emissions in countries such as China, India and Russia will increase.*

Palladium

Auto company purchases of palladium rebounded in 2003 as much less metal was drawn from stocks. Consumption of palladium in autocatalyst manufacture, however, continued to be adversely affected by thrifting.

The dental market for palladium-based alloys began to recover in the USA and Europe in 2003, but demand in Japan fell sharply due to changes in the state-run subsidy programme for dental treatment.



Palladium

Palladium

Autocatalyst

In 2003 purchases of palladium by the global autocatalyst industry improved by 13 per cent to 3.46 million oz, an increase of 410,000 oz compared with 2002. The recovery in purchases was almost entirely due to the fact that, having largely run down very sizeable palladium inventories in 2002, the US auto industry sourced the majority of its palladium from the market last year. However, the underlying use of palladium on autocatalysts in the USA dropped significantly as thrifting programmes cut average palladium loadings.

In Europe, purchases of palladium fell due to a slump in sales of gasoline powered cars, primarily a result of another strong rise in diesel car market share. Japanese autocatalyst purchases of palladium improved moderately but demand in the Rest of the World was hit by continued thrifting in many markets and a steep fall in Mexican light vehicle production.

Europe

European demand for palladium in autocatalysts dropped by 12 per cent in 2003 to 1.21 million oz, down from 1.37 million oz the year before. The primary cause was a substantial fall in sales of gasoline powered cars; diesel cars gained further market share and total car sales in the region weakened. Sales of gasoline cars slumped by 11 per cent, falling below 8 million units for the first time in over a decade. The market share held by gasoline cars in Western Europe slipped to less than 57 per cent – five years ago that figure was around 75 per cent. With the ratio of palladium to platinum use in gasoline autocatalysts close to 4:1 on average in Europe, the drop in gasoline vehicle sales had a marked effect on demand for palladium.

Thrifting also had a negative impact on purchases of palladium by European auto makers in 2003; average palladium loadings fell by around 4 per cent across the gasoline vehicle fleet as a whole as some manufacturers continued to focus on minimising their overall pgm use. In addition, decisions taken in 2000 and 2001 by several car companies to reduce palladium use in favour of platinum continued to adversely affect demand for the former in 2003, although the impact was less than the year before.

With palladium trading at a widening discount to platinum throughout 2003, some manufacturers moved to reverse the process of switching, aiming to cut future platinum usage on gasoline vehicle models through greater reliance on palladium. In the short-term, however, further thrifting of palladium loadings and growth in the market share taken by diesel cars will more than offset any increase in palladium use.

Japan

Car companies in Japan purchased 540,000 oz of palladium in 2003, an increase of 4 per cent (20,000 oz) compared with 2002. Palladium purchases rose largely because Japanese manufacturers used little or no metal from inventories in 2003, whereas there had been some use of stocks in 2002. Car sales increased by 1.5 per cent in Japan in 2003 but car production weakened, a reflection of the fact that a growing proportion of vehicles manufactured by Japanese car companies is being produced overseas.

The underlying use of palladium in autocatalysts in 2003 slipped lower as thrifting reduced average palladium loadings modestly. This fall is likely to be reversed in 2004. Certain manufacturers plan to shift overall pgm ratios more towards palladium than platinum, whilst average loadings are forecast to edge upwards in advance of the next phase of Japanese vehicle emissions legislation, due in 2005. The combined effect on metal demand, however, is expected to be fairly small.

North America

North American vehicle manufacturers purchased 1.21 million oz of platinum in 2003 – almost double the volume bought in 2002, when demand for new metal was heavily suppressed by the use of an estimated 1.4 million oz of metal from inventories. Certain auto companies continued to run down their remaining palladium stocks in 2003 but purchased a much greater proportion of their metal requirements from the market.

This, however, has to be set against a substantial fall in the underlying use of palladium in autocatalysts in North America, which dropped by more than 20 per cent in 2003. The decline was a result of the intensive thrifting of palladium loadings that was achieved by catalyst manufacturers, prompted by pressure from US auto makers following the palladium price spike in 2000 and 2001.

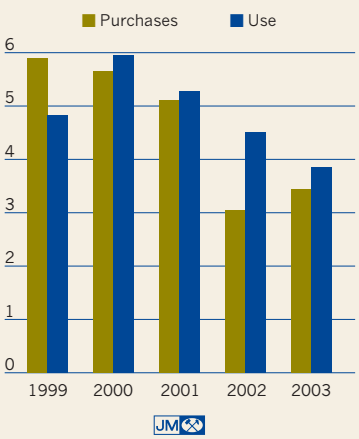
Changes in autocatalyst pgm ratios in response to the large differential between the price of platinum and

Palladium Demand: Autocatalyst
'000 oz

	2002	2003
Europe	1,370	1,210
Japan	520	540
North America	640	1,210
Rest of the World	520	500
Total	**3,050**	**3,460**
Autocatalyst recovery	(370)	(410)

JM

Palladium Autocatalyst Demand 1999-2003
Million oz



JM

Palladium

The manufacture of vinyl acetate monomer is a major application for palladium-based catalysts, and capacity in Asia expanded in 2003.

palladium started to emerge in 2003, with US auto makers in the vanguard of moves to replace platinum-rhodium catalysts with platinum-palladium-rhodium or palladium-rhodium products. That said, the process of catalyst change is evolutionary and the impact on use of palladium last year was slight.

Rest of the World

Demand for palladium used in autocatalysts in the Rest of the World dropped by 4 per cent (20,000 oz) in 2003, easing to 500,000 oz. A 14 per cent decrease in light vehicle production in Mexico had a significant impact on autocatalyst demand for palladium. Mexican vehicle output fell from over 1.7 million units to around 1.5 million due to a combination of poor domestic sales (which were hampered by the weak economy) and lower exports to the USA.

At the same time, thrifting of palladium reduced average loadings in autocatalysts produced in Mexico and elsewhere. The negative effect of this outweighed the positive impact of higher car production in China, India and several other countries in Asia.

Autocatalyst Recovery

The volume of palladium recovered from scrapped autocatalysts climbed by 11 per cent to 410,000 oz in 2003. As with platinum, the growth in the rate of recovery was greatest in Europe (up by 56 per cent to 70,000 oz) as the percentage of scrapped cars fitted with catalytic converters increased and greater efforts were made to remove and recycle catalysts.

The rise in the rate of recovery of palladium from autocatalysts in North America, where the auto recycling industry is more mature, was far more modest (up by 4 per cent to 270,000 oz). A substantial increase, however, is forecast for 2004 and beyond as greater numbers of vehicles with heavily loaded palladium catalysts (manufactured from the mid-1990s onwards) reach the end of their lives.

Palladium Demand: Chemical
'000 oz

	2002	2003
Europe	70	65
Japan	20	20
North America	75	70
Rest of the World	90	95
Total	**255**	**250**

JM

Chemical

Purchases of palladium for use in bulk chemical manufacturing applications softened slightly in 2003, easing to 250,000 oz. Demand for palladium from the nitric acid industry improved moderately, helped by lower metal prices, but demand from the process catalyst sector fell in Europe and North America.

The fall in the price of palladium and the strong rise in the price of platinum made the use of palladium catchment gauze more cost-effective for nitric acid producers in 2003. In addition, some manufacturers shifted from 5Rh/95Pt catalyst alloys (5 per cent rhodium, 95 per cent platinum) to 5Pd/5Rh/90Pt alloys (adding 5 per cent palladium in place of platinum). However, producers' costs and margins were under severe pressure for much of the year and investment in replacement catalysts and catchment gauzes was generally kept to a minimum. As a result, palladium demand increased by only a few thousand ounces.

In the process catalyst sector, expansion of manufacturing capacity for bulk chemicals produced using palladium catalysts continued in Asia, with new vinyl acetate monomer (VAM) and purified terephthalic acid (PTA) plants coming on stream. This was offset, however, by reductions in manufacturing capacity for PTA and hydrogen peroxide in Europe and North America.

Dental

In 2003 demand for palladium from the dental alloys market fell by 8 per cent to 725,000 oz. Demand for palladium-based alloys had been expected to continue to recover from the recent low of 2001 in response to the fall in the price of the metal. However, in the largest market, Japan, a reduction in the level of government subsidies available for dental treatment led to a sharp drop

in palladium alloy demand. This overshadowed improvements in the European and North American markets.

In Japan, the cost of the 20 per cent palladium alloy (kinpala) used in dental treatment is heavily subsidised by the government. In April 2003, however, the percentage of the cost that is reimbursed by the state-run programme was cut from 80 per cent to 70 per cent. This was the second reduction in the level of state subsidies in four years. The subsequent rise in treatment costs payable by patients resulted in an immediate and substantial drop in the number of visits to dentists, with people keen to postpone treatment for as long as possible. The knock-on effect on kinpala alloy demand was rapid and severe, which in turn resulted in purchases of palladium for alloy manufacture dropping by 20 per cent to just 405,000 oz – the lowest level for more than a decade. Demand is expected to improve in 2004 as the number of dental procedures undertaken starts to pick up but the recovery is likely to be slow.

European demand for palladium in dental alloys improved in 2003, rising by 15,000 oz to 70,000 oz. In most countries the substitution of palladium with alternative alloys and porcelain products appears to have been permanent. The exception is Italy, where use of precious metal dental alloys has remained relatively high. In Italy, the fall in the price of palladium coupled with the rise in the price of gold resulted in a move away from high-gold alloys back towards palladium-based formulations.

The lower price of palladium and higher cost of gold also encouraged a recovery in demand for the former in the North American dental market. Purchases of palladium climbed by 9 per cent to 235,000 oz as high-gold alloys lost market share. Should the price of palladium remain at a significant discount to that of gold throughout 2004, further modest growth in palladium demand can be expected.

Palladium Demand: Dental
'000 oz

	2002	2003
Europe	55	70
Japan	505	405
North America	215	235
Rest of the World	10	15
Total	**785**	**725**

JM

Electronics

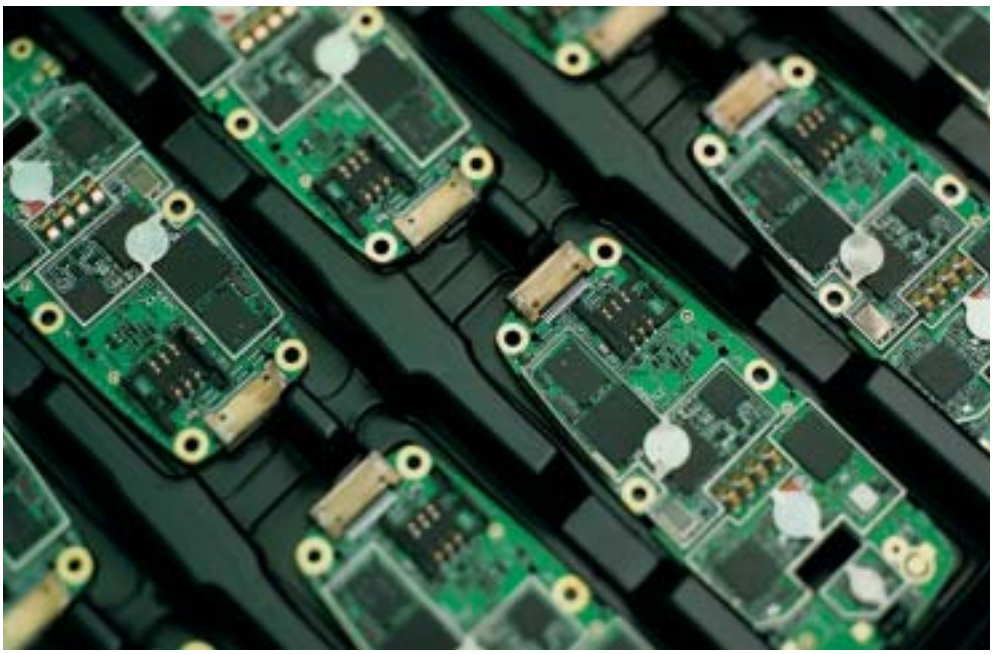
The use of palladium in the production of electronic components fell by 7 per cent in 2003. The decline in consumption was due to a combination of the ongoing miniaturisation of capacitors and hybrid integrated circuits, and further thrifting of precious metal use throughout the industry. Purchases of palladium, however, by manufacturers of electronic components recovered by 18 per cent in 2003 to 895,000 oz. Metal demand more closely reflected the level of component orders as excess inventories, which had depressed purchases of palladium in 2002, had been depleted by the beginning of 2003.

Multi-layer ceramic capacitors (MLCC) remain the largest electronics application for palladium. Shipments of MLCC grew by almost 18 per cent in 2003, rising to approximately 600 billion compared with

Palladium Demand: Electronics
'000 oz

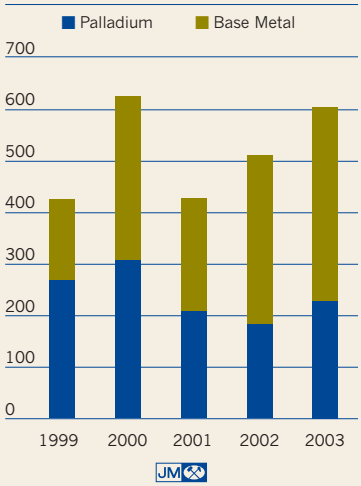
	2002	2003
Europe	85	85
Japan	140	220
North America	210	215
Rest of the World	325	375
Total	**760**	**895**

JM



The ongoing miniaturisation of electronic components resulted in a fall in the consumption of palladium in the manufacture of multi-layer ceramic capacitors in 2003.

MLCC Production by Electrode Type 1999-2003
Billions



Data Source: Paumanok Publications, Inc.

a little over 500 billion the year before. The surge in component orders was based on a combination of rising demand for mobile phones, personal computers and automobile electronics, with the Chinese market for consumer goods growing particularly rapidly.

The output of palladium-based MLCC grew slightly faster than the sector as a whole, rising by 21 per cent in 2003. The erosion of palladium MLCC market share by nickel-based capacitors reached a plateau in Japan (by far the largest centre of production) and was reversed somewhat in China as new production capacity for palladium MLCC came on stream. This did not, however, result in greater use of the metal. On the contrary, consumption of palladium actually fell marginally year-on-year due to a combination of miniaturisation and thrifting.

The average size of MLCC has been declining for many years and this global trend accelerated in 2003 with the introduction of a new generation of products. These capacitors are approximately 70 per cent smaller in volume terms than their predecessors, and so contain substantially less palladium. Rapid uptake of these smallest capacitors is expected in the mobile phone industry; the pressure to fit more components into a given volume is becoming more intense as phone functionality expands. In addition, MLCC manufacturers continued to thrift their use of palladium in 2003. The average palladium content of conductive pastes used by the industry has fallen from around 30 per cent to 20 per cent since 1998.

Thrifting also affected demand for palladium in hybrid integrated circuits (HIC) in 2003. Component manufacturers have successfully reduced their palladium consumption substantially since the price of the metal peaked in early 2001. In addition, the market share taken by palladium-free HIC has expanded. Consequently palladium use in HIC production slumped by 35 per cent in 2003.

Demand for palladium in the plating of lead frames and connectors increased in 2003 as the price of palladium fell significantly below that of gold. The rise in demand was marginal, however, due to continued miniaturisation of components and further reductions in precious metal use through the application of thinner coatings.

Demand for line feed resistors (also known as surge protection resistors) increased only slightly in 2003 – a key application for these resistors is telecommunications infrastructure and a significant recovery in activity did not materialise as expected. On a more encouraging note, good demand for varistors and actuators containing palladium was seen from the automotive and mobile phone sectors.

Other

Purchases of palladium by the jewellery fabrication and other industries weakened by 3 per cent in 2003, slipping to 340,000 oz. Demand from the Japanese jewellery industry edged lower as demand for platinum alloys containing palladium fell and recycling of inventories grew. Demand from the Chinese jewellery sector also softened, with other metals increasingly used in place of palladium in white gold alloys. Use of palladium in most other applications was stable.

Purchases of palladium for use in jewellery alloys dropped by 10,000 oz to 250,000 oz in 2003. Japan accounted for approximately two thirds of total palladium jewellery demand; platinum alloys containing 5 to 15 per cent palladium are preferred by many Japanese fabricators. Consequently, the drop in retail sales of platinum jewellery and the increased volumes of metal recycled throughout the industry in 2003 depressed demand for palladium. The effect was lessened somewhat by an increase in production of white gold jewellery, in which palladium can be used as a whitening agent.

Palladium is also a constituent of some platinum and white gold jewellery alloys produced in China, although alternatives are much more commonly used than in Japan. The fall in platinum jewellery output in China in 2003 and the increased use of metals such as nickel, zinc and tin in white gold alloys resulted in demand for palladium softening, despite rising retail sales of white gold jewellery.

Demand for palladium-based hydrocracking catalysts from the worldwide petrochemicals industry was stable, maintained by top-up orders from existing installations. Hydrocracking capacity is expanding in North America as a result of legislation to lower the sulphur content of gasoline but operators have generally preferred to install less expensive base metal catalysts in new plants.

The use of palladium in other minor applications such as brazing alloys, catalysts for stationary emissions control applications, and photographic film was broadly unchanged in 2003.

Palladium Demand: Jewellery & Other
'000 oz

	2002	2003
Europe	50	55
Japan	175	170
North America	45	40
Rest of the World	80	75
Total	**350**	**340**

JM

Other PGM

Other Platinum Group Metals

Rhodium

Net purchases of rhodium rose by 6 per cent in 2003 to 627,000 oz. Overall use of the metal in autocatalysts grew strongly as average rhodium levels increased ahead of tighter emissions legislation. The level of purchases made by auto makers, however, was dampened by the continued use of rhodium stocks. Demand from the glass industry fell as the rate of capacity expansion slowed and manufacturers reduced their overall pgm holdings. Demand for rhodium-based chemical catalysts softened.

Autocatalyst

The global auto industry purchased a total of 665,000 oz of rhodium in 2003, an increase of 11 per cent (66,000 oz) compared with the year before. Actual use of the metal in autocatalyst manufacture, however, was higher than this as certain US auto companies continued to deplete their rhodium inventories, consequently cutting their purchasing requirements.

The growth in use of rhodium in autocatalysts was greatest in the USA and Japan. Tighter emissions regulations are due to be introduced in each country (from 2004 onwards in the USA and in 2005 in Japan), and in both cases the permissible levels of NOx emissions will be cut substantially. Rhodium is a particularly effective catalyst for the conversion of NOx to nitrogen and so auto makers have increased average rhodium loading levels in many instances.

The increase in average rhodium loading levels in the USA in 2003 was also a result of the intensive platinum and palladium thrifting programmes that US car companies adopted. In many catalyst systems a small rise in the rhodium content can help to maintain emissions conversion rates when platinum or palladium loadings are reduced. This is cost-effective as rhodium is used in much smaller proportions than platinum and palladium. The advantage of using rhodium was reinforced by the fall in the price of the metal from over $2,000 per oz in 2001 to $500 in 2003.

European auto manufacturers also increased average gasoline vehicle rhodium loading levels in 2003, both to meet the Euro IV emissions standards that come into force from 2005 vehicle models onwards, and to enable thrifting of platinum and palladium. However, the effects of higher loadings on rhodium demand were outweighed by a 7 per cent drop in production of gasoline cars in 2003 – the net result being that purchases of rhodium by car companies weakened.

Demand for rhodium in the Rest of the World increased by 8 per cent in 2003, primarily driven by the rapid expansion of car manufacturing and sales in China and India.

The recovery of rhodium from scrapped autocatalysts jumped by 24 per cent to 123,000 oz in 2003. In common with platinum and palladium, the largest rise was seen in the USA, where the volume of rhodium recovered surged by 30 per cent. The rapid rise in the platinum price helped to boost overall collection and recycling rates for scrapped catalysts. In addition, the average rhodium content of catalysts being recycled increased, a reflection of the move towards higher rhodium loading levels that occurred during the mid-1990s as new emissions legislation (targeting NOx in particular) was introduced.

Recovery of rhodium in Europe also grew strongly in 2003, albeit from a much smaller base. The increase was due to a rise in recovery rates, driven by the imminent introduction of new recycling legislation, as well as a similar rise in average rhodium loading levels as was seen in the USA.

Other

Purchases of rhodium for use in chemical, glass and other applications weakened by 7,000 oz to 85,000 oz in 2003. Demand for the metal for the manufacture of catalysts for the chemicals industry and platinum alloys for the glass industry fell, while use of rhodium in electrical and other applications was little changed.

Demand for rhodium from the chemicals industry slipped by 5 per cent to 37,000 oz in 2003. The decline was largely due to a reduced rate of capacity expansion for bulk chemicals such as oxo-alcohols and the conversion of a number of acetic acid plants from rhodium-based catalyst technology to iridium-ruthenium catalysts. Consumption of rhodium in platinum alloys for use in nitric acid gauze softened.

Glass manufacturers purchased approximately 31,000 oz of rhodium in 2003, 16 per cent less than the year before. Demand for rhodium was affected by the high price of platinum, which led glass companies to minimise their holding of rhodium-platinum alloy components, and to increase their sales of scrap items back to refiners. In addition, although new glass manufacturing capacity continued to be added in Asia, the rate of expansion was lower than in 2002.

Rhodium Supply and Demand
'000 oz

	2002	2003
Supply		
South Africa	490	545
Russia	90	140
North America	25	20
Others	10	15
Total Supply	**615**	**720**
Demand		
Autocatalyst: gross	599	665
recovery	(99)	(123)
Chemical	39	37
Electrical	6	6
Glass	37	31
Other	10	11
Total Demand	**592**	**627**
Movements in Stocks	**23**	**93**

JM

The manufacture of hard disks provided a growing market for ruthenium in 2003.

Other PGM

Ruthenium Demand by Application
'000 oz

	2002	2003
Chemical	101	141
Electrochemical	116	120
Electronics	140	157
Other	63	78
Total	**420**	**496**

JM

Ruthenium & Iridium

Purchases of ruthenium surged by 18 per cent in 2003 to 496,000 oz. Use of the metal in chemical catalyst applications jumped by 40,000 oz and demand from the electronics industry also grew strongly. Demand for iridium also recovered rising by 30 per cent to 103,000 oz. The growth was driven by increased use of iridium-based catalysts in the chemicals industry and a turn-around in orders for iridium crucibles from the electronics sector.

Demand for ruthenium for use in chemical process catalysts jumped by almost 40 per cent in 2003 to 141,000 oz. Much of the increase was driven by expansion of acetic acid manufacturing capacity. The relatively new Cativa® acetic acid manufacturing technology utilises an iridium-ruthenium catalyst. Because the technology offers a number of technical benefits, it was installed in several new plants and was also retrofitted in some existing facilities. Demand for ruthenium-based products used in proprietary chemical applications also increased in 2003.

Consumption of ruthenium in resistors and other electronic components improved by 12 per cent last year, rising to 157,000 oz. In 2002 an overhang of component inventories and excess stocks of ruthenium pastes dampened purchases of the metal but these had been depleted by 2003. During the year demand for consumer and automotive electronics increased significantly, driving a rebound in component manufacturing rates.

Electronic demand for ruthenium also benefited from growing use of the metal in hard disk drives. The addition of a very thin layer of ruthenium to the magnetic coating of hard disks can substantially increase data storage density. As the technology began to penetrate the hard disk sector in 2003, demand for ruthenium sputtering targets increased.

Electrochemical demand for ruthenium increased moderately in 2003 to 120,000 oz. Ruthenium is used as an electrode coating in older chlor-alkali plants utilising the mercury or diaphragm process. Electrode recoating programmes at several of these large plants boosted ruthenium demand last year. Over the longer term, however, ruthenium demand is expected to weaken as more plants switch to modern membrane technology that uses ruthenium-iridium electrode coatings rather than ruthenium only.

Demand for ruthenium-titanium alloys used in the manufacture of corrosion-resistant pipes was little changed in 2003, and consumption of ruthenium in jewellery alloys was also broadly stable.

As with ruthenium, the spread of the Cativa® acetic acid manufacturing technology boosted demand for iridium in 2003, total chemical industry demand doubling to 20,000 oz. Electrochemical demand for iridium, however, was unchanged as electrode recoating programmes at plants using membrane technology progressed steadily.

Total electronics demand for iridium increased to 32,000 oz in 2003 as the upturn in the global electronics industry began to feed through to improved demand for iridium crucibles, particularly in Asia. The crucibles are used in the manufacture of high purity crystals, which form the basis of components used in applications such as mobile telecommunications hardware, and medical lasers and scanners.

Consumption of iridium in the manufacture of high performance spark plugs grew but the sector remains small in volume terms. Use of the metal in most other applications, such as jewellery alloys and cathodic protection, was broadly flat.

Iridium Demand by Application
'000 oz

	2002	2003
Chemical	10	20
Electrochemical	23	23
Electronics	21	32
Other	25	28
Total	**79**	**103**

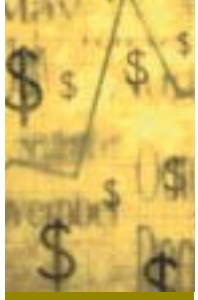
JM

Other PGM Supplies

Supplies of rhodium climbed by 17 per cent in 2003 to 720,000 oz. South African shipments of the metal expanded by more than 11 per cent to 545,000 oz, reflecting both increased mine production of pgm ore, plus an increase in the proportion of UG2 ore mined. The average rhodium grade of UG2 is typically double that of the Merensky Reef. Russian sales of rhodium also grew substantially in 2003, rising by 50,000 oz to an estimated 140,000 oz.

The increase in availability of rhodium outstripped the rise in demand for the metal and the market moved further into surplus during the year. This was reflected in the price, which fell from a peak of $650 in January to $500 by the middle of the year.

The situation was similar for both iridium and ruthenium; rising supplies from South Africa were more than sufficient to meet improved demand for the two metals.



Prices and Futures Markets

Platinum

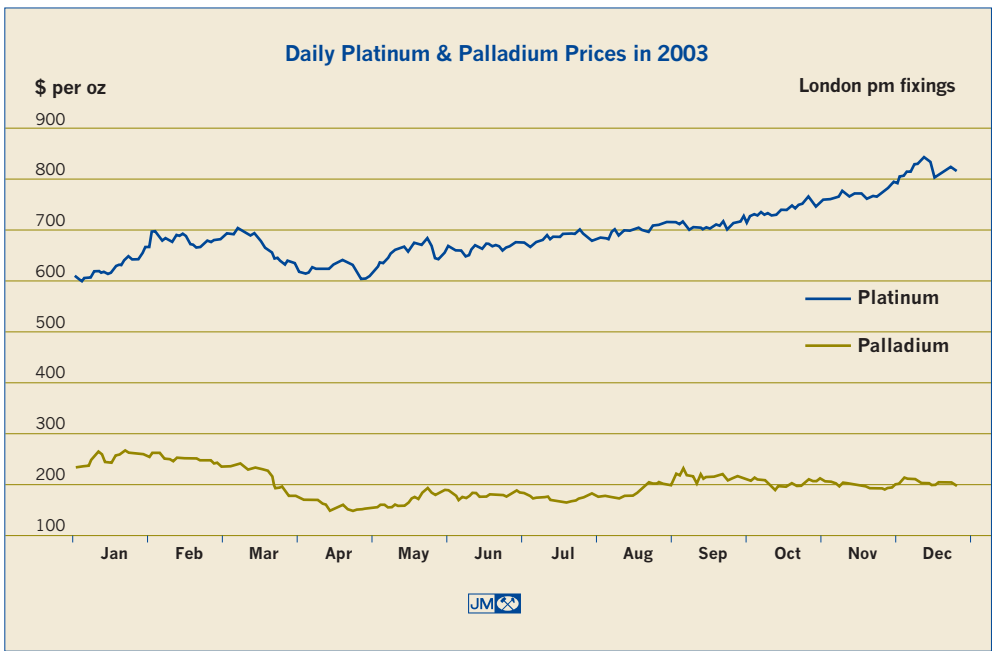
In 2003 the impressive rise in the platinum price that had begun the previous year intensified; after having increased by $150 in 2002 it climbed by a further $242 during 2003. The metal started the year strongly, progressing from an opening fixing of $600 to just over $700 in early February. Demand from industrial users and the Chinese jewellery industry was firm, and with availability tight short-term lease rates climbed rapidly. At the same time funds and individual investors rebuilt speculative positions on both NYMEX and TOCOM following long liquidation towards the end of 2002.

The platinum price dipped to $664 in mid-February, regained $700 in early March, and then dropped back towards $600 through into April on a wave of long liquidation that flowed across the commodities markets as a whole. From May onwards, however, the platinum price was driven upwards in an accelerating rally, punctuated by occasional bouts of fund profit-taking, reaching a peak of $842 in December.

The exceptional performance of the price from May onwards was due to a confluence of positive supply/demand fundamentals for the metal and a wider commodities bull market. The latter was driven by hedge funds and other investors seeking higher returns than those offered by equities and bonds *(see panel on page 47 for details)*.

The platinum market began 2003 with a strong rally, the price climbing throughout **January** from an opening fixing of $600 in London on the 2nd to $669 on the 31st. Buying of physical metal by industrial users picked up following the typically slack pre-Christmas period. At the same time, funds that had liquidated long positions on NYMEX at the end of 2002 became net buyers of both gold and platinum futures as the dollar weakened significantly versus the euro. The news that Lonmin had suffered an explosion at its new smelter in South Africa contributed to the bullish tone. Speculative buying and short-covering on TOCOM provided further momentum as the yen strengthened against the dollar, and with physical availability tight, heavy borrowing pushed lending rates briefly above 20 per cent.

Further substantial buying on TOCOM by both Japanese investors and overseas funds, plus a solid level of bids across the fixings, resulted in the spot price surging to hit $700 on the 3rd of **February**. Offers touched $710 in Asia on the 4th as dealer short-covering came into the market and one month lease rates again spiked towards 20 per cent. However, bids for physical metal then fell away rapidly, and as funds started to take profits the spot price slumped to $676 on the 6th. From then on the price bounced between $664 and $700, moving in response to fund activity and the availability of metal for lending. Platinum closed February with a fixing of $681, the spot market being

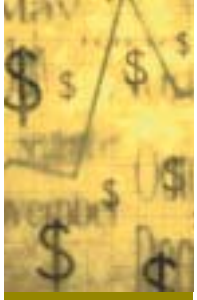


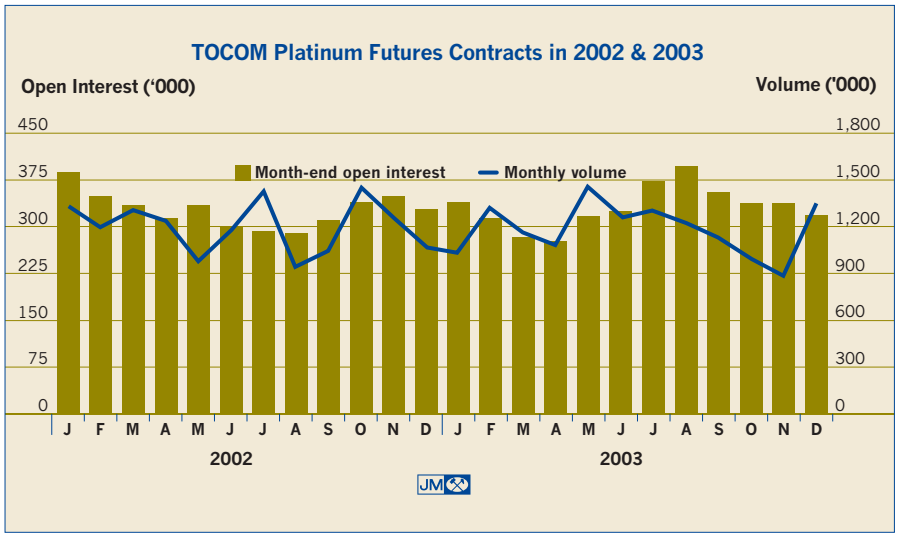
Average PGM Prices in $ per oz

	2002	2003	Change
Platinum	539.69	691.86	28%
Palladium	337.23	200.61	– 41%
Rhodium	838.05	530.27	– 37%
Iridium	293.57	93.07	– 68%
Ruthenium	66.41	35.04	– 47%

Platinum and palladium prices are averages of London am and pm fixings. Other pgm prices are averages of Johnson Matthey European base prices.

JM





supported by short-term lease rates in the mid-teens.

Early **March** saw further concerted buying of platinum futures on TOCOM as the dollar lost more ground versus the yen and euro. The price of platinum climbed to $699 on the 5th, then ran up to $705 on the morning of the 11th as Japanese investors switched cash out of the rapidly falling equities market and into precious metals. As in February, however, the rise to over $700 resulted in a fall in bids for metal from industrial users and platinum slipped back to trade between $688 and $700 for the next seven days.

On the 18th a rapid sequence of long liquidation began on TOCOM across several commodities, starting with a sharp drop in the price of crude oil and moving into metals. Stop-loss sell orders were hit as the platinum price started to fall, and by the end of trading in New York on the 19th it had dropped to $673. The dollar strengthened sharply against the yen on the 20th spurring more selling in Tokyo, and the price continued to weaken over the following week. By the 28th of March, platinum had slumped to $625.

After a brief rebound to $645, the platinum price weakened again in early **April** as a sharp strengthening of the dollar against the yen (and an associated drop in the gold price) triggered a further round of selling on the futures markets. With physical demand still soft, particularly from Chinese jewellery fabricators, the price slipped from $642 on the 1st to fix at $611 on the morning of the 8th.

At that level physical bids increased, whilst on NYMEX funds began rebuilding long positions, squeezing speculators that had gone short when the platinum price was falling. Platinum moved up to $625 on the morning fix of the 9th, traded steadily for several days, then edged up towards $640. However, when increased volumes of physical metal were offered the marked turned down again. Investor sentiment turned bearish, with concerns starting to be aired about the possible impact of the SARS virus on Chinese jewellery demand. Long liquidation of futures positions pushed the platinum price downwards and the metal ended the month fixed at $603.

The platinum price staged a strong rally in **May** as the increasing weakness of the dollar versus the euro and yen boosted purchases of platinum by industrial users and encouraged investors to rebuild long positions. Speculators also took advantage of tight physical availability to squeeze the market; short-term lease rates jumped from less than 8 per cent to over 20 per cent and the price rose from $606 on the 1st to $685 on the 27th. The dollar then recovered some ground against major currencies, triggering long liquidation of futures positions by funds. With offers of physical platinum also increasing, lease rates swiftly fell back below 10 per cent. The platinum price slid in tandem, finishing May at $642.

The start of **June** marked the beginning of an increasingly rapid and occasionally volatile climb in the price of platinum that lasted until almost the end of the year. Most of the momentum came from fund buying of derivatives, although physical demand also remained solid. With banks and brokers offsetting their exposure to the funds' long futures positions by buying and then lending physical metal, lease rates began moving inversely to the spot price.

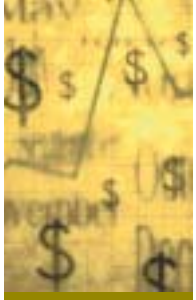
The platinum price jumped from under $640 on the 2nd June to $669 on the 4th and 5th, driven by dealers and funds opening new long positions on NYMEX and by heavy trade on TOCOM. The unpredictable market then turned around again as increased lending pushed short-term lease rates lower and the spot price subsided to $646 on the 11th. Good physical demand was found at this level, and platinum moved back up to trade between $660 and $670 for much of the remainder of the month.

Funds continued to be net buyers of platinum futures (as well gold and base metals) throughout much of **July**, largely inspired by moves in the foreign exchange markets. In particular, the rapidly increasing strength of the rand (which moved from over R8 to the dollar at the start of June to less than R7.4 by the end of July) was seen as bullish for platinum because of its

Platinum Prices in 2003
London am and pm fixings, $ per oz

	High	Low	Average
Jan	671.00	600.00	629.63
Feb	703.00	664.00	682.25
Mar	705.00	625.00	675.76
Apr	642.00	603.00	624.70
May	685.00	606.00	650.73
Jun	674.00	638.00	661.75
Jul	700.00	665.00	681.93
Aug	709.00	677.00	692.50
Sep	714.00	696.00	705.24
Oct	762.00	710.00	732.38
Nov	772.00	738.00	760.25
Dec	842.00	770.00	807.75

JM



potentially negative effect on the earnings and expansion plans of South African pgm producers. Further dollar weakness against the yen also fuelled continued buying of futures through TOCOM. As a result the platinum spot price climbed from an opening fixing of $671 to hit $700 on the 29th. With physical trade becoming increasingly light, however, and the dollar recovering somewhat, the price then slipped to $684 on the 31st.

A degree of investor profit-taking kept the platinum price close to $680 during the first 10 days of **August** and physical trade was thin. From the 11th onwards, however, speculative buying of the metal resumed strongly and funds targeted investors holding short positions on TOCOM. With gold also rallying, platinum climbed to breach $700 by the 20th and the price fixed at a new high for the year of $709 on the 27th. Although volumes of physical trade diminished even further, fund buying on NYMEX ensured the platinum price ended the month well supported at $707.

The speculative buying that had pushed the platinum price above $700 in late August continued into early **September** as the dollar dropped sharply against the euro, driving the metal to a fixing of $714. A degree of fund profit-taking resulted in a price correction back under $700 in mid-month but this moderate dip encouraged an increase in physical purchasing, particularly from Chinese jewellery fabricators who were stocking up ahead of the October National Day holiday. The price consequently regained its previous high of $714 on the 25th. Volatile trading, related in part to the imminent expiry of options, marked the last week of the month but platinum ended September firmly at $710.

The price of platinum resumed its firm upward trend in **October**, with speculative buying of the metal once again providing most of the momentum. The price jumped from an afternoon fixing of $711 on the 2nd to $726 on the 3rd as Anglo Platinum said that it would release an update on its expansion programme during November. The expectation that the company would reveal a substantial cut in its schedule of expansions added to the already bullish view of investors. After being knocked back to $710 on the 6th the platinum price rose rapidly throughout the month, peaking at a fixing of $762 on the 30th. In contrast, however, one-month lease rates eased, subsiding from 7.5 per cent to around 4.5 per cent.

A flurry of profit-taking and increased offers of

Fund buying of pgm

The concerted buying of commodities by funds throughout 2003 and into 2004 has been based on a combination of many factors: low to negative real interest rates in the USA and Japan, the relatively poor performance of major equity markets from 2001 onwards, unattractive bond yields, the weakening of the dollar versus major currencies, the prospects of continued strong economic growth in China, and improving industrial output in the USA and Japan.

The effect of the depreciating dollar in particular on the price of platinum in 2003 was substantial. Statistically, the relationship between two variables can range from 1.0 (a perfect positive relationship) down to –1.0 (a perfect inverse relationship – i.e. as one variable goes up, the other moves down proportionally). The inverse correlation between the price of platinum and the $:rand exchange rate over the year was –0.76, with the $:euro the link was –0.71 (rising to –0.83 for the second half), whilst the relationship with the $:yen exchange rate was even stronger at –0.86.

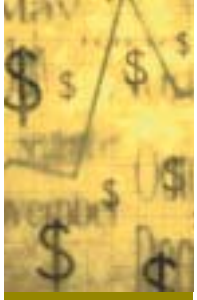
Of course, fund buying of hard commodities is also tied in with market fundamentals. For platinum the key factors are several years of deficit between primary supply and demand, a perception of increasing supply side risk (largely based on the rising strength of the rand), the resilience of Chinese jewellery demand, and a favourable outlook for autocatalyst use of the metal. In these respects, the platinum market shared close similarities with those of nickel and copper in 2003 (growing market deficits, Chinese buying a major component of demand, increasing supply side risks). Consequently, the positive correlation between the platinum price and that of nickel and copper (LME cash price) last year was remarkably high at 0.93 and 0.94 respectively.

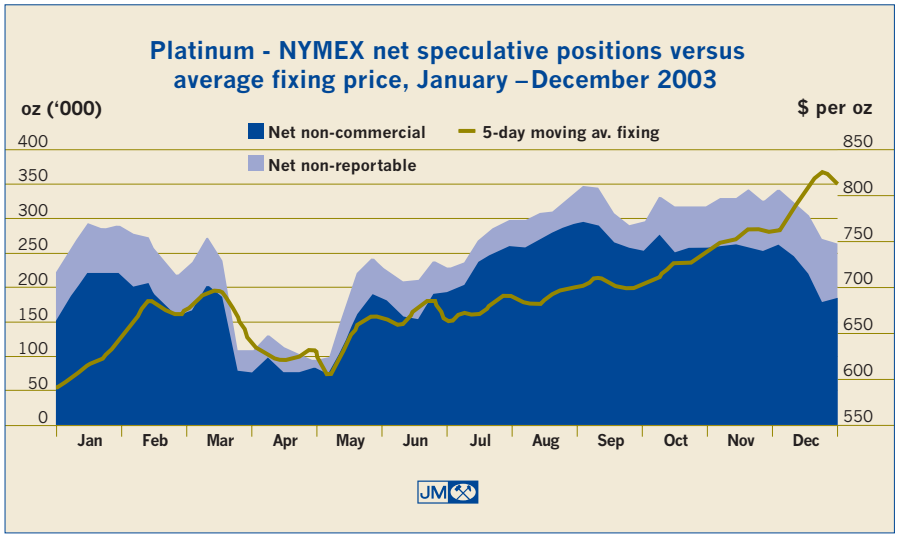
The appeal of commodity markets has not been confined to hedge funds. Mutual and pension funds have been increasing their exposure to 'alternative' investments, whilst smaller investors have participated on NYMEX via Commodity Trade Advisors as well as through over-the-counter (OTC) deals. Investment banks have increasingly marketed commodity related derivatives such as warrants and certificates to their clients.

For palladium, however, it was (and is) harder to make a bullish case for investment based on the metal's fundamentals. The market has been in a position of oversupply since 2001. Supply will continue to grow strongly from the expansion of pgm mining in South Africa and from increased recycling of autocatalysts and electronic waste. Even with the most optimistic projections for autocatalyst, electronic and dental demand, the palladium market appears set to remain in substantial surplus. Nevertheless, as the price of platinum climbed in 2003, fund managers increasingly inferred that the differential between it and the price of palladium would become unsustainably large. With the risk of a downward correction in the platinum price considered small, due to the metal's strong fundamentals, the conclusion was that the price of palladium would almost certainly have to rise.

In addition, the platinum and palladium markets are very small compared with other commodities, and are minute compared with equity, fixed income or foreign exchange markets. Consequently, significant activity by hedge funds can move the price in either direction regardless of the fundamentals. Furthermore, price trends can rapidly become self-sustaining as funds that trade on momentum or technical indicators are drawn into the market.

The small size of the pgm markets, however, and their relatively high volatility also increases the risks for investors. Palladium in particular can be a highly illiquid financial instrument, as was shown by the suspension of the TOCOM contract in 2000. The risk, therefore, of being unable to close out a position when the market turns can be significant.





Non-commercial futures positions are those held by hedge funds, bullion banks and others for speculative purposes. The non-reportable category comprises investors whose total positions fall below the limit specified by the US Commodity Futures Trading Commission.

physical metal took the platinum price down to $738 on the 3rd of **November** before speculative buying returned to drive the price higher once again. By the close of trading in New York on the 4th offers of platinum had passed $750, the price regained the $760 mark on the 11th, then reached $772 on the 13th as the dollar's slide against the euro, yen and rand resumed and the price of gold climbed over $390. Platinum then traded quietly between $760 and $770 for much of the rest of the month, with steady industrial demand underpinning the market. Lease rates, however, continued to soften, one-month offers dropping to around 3.5 per cent.

Further weakening of the dollar against major currencies propelled both platinum and gold prices higher in **December**. Meanwhile, Chinese purchases of metal for jewellery fabrication accelerated in advance of the Chinese New Year holiday in January 2004. In addition, Anglo Platinum confirmed market expectations by announcing a substantial scaling-back of its expansion programme. All these factors, combined with a squeeze on short-term lease rates, resulted in the platinum price soaring from $770 on the 1st to a fixing of $842 on the morning of the 18th – a price exceeded only once before, back in March 1980.

Profit-taking ahead of the end of the calendar year then came to the fore, starting with heavy trade on TOCOM later the same morning. As the selling accelerated the price slumped, dropping to $825 by the close of trade in New York. The profit-taking continued through to the 22nd, pushing the price down to $796. The drop under $800 stimulated a brief surge of buying from China before the market steadied and ended the year with a fixing of $814.

From its low of $600 at the start of 2003 to the peak fixing of $842 on 18th of December, the platinum price appreciated by 40 per cent. However, given the weakening of the US dollar versus most other major currencies, particularly during the second half of the year, the rise was less pronounced for European and Japanese buyers. The platinum price increased by 22 per cent in yen and by 13 per cent in euros over the course of the year. The effect of currency movements on the South African pgm producers was even more pronounced: the platinum price in rand increased by just 5 per cent due to the 23 per cent appreciation of the South African currency versus the dollar.

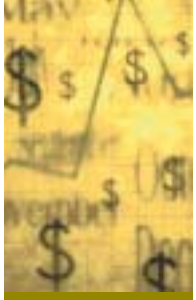
Palladium

The contrast between the price of palladium and that of platinum remained pronounced in 2003; palladium started the year at $234 and ended it below $200. This occurred despite very substantial fund and investor buying of the metal on the futures exchanges and in the over-the-counter market. The price of the metal was held in check by the softness of industrial demand and the readiness of suppliers to sell into any signs of price strength.

The palladium price made solid gains during the first few weeks of 2003, driven by a brief upturn in industrial buying, a drop in physical availability, and the liquidation of short futures positions. The price climbed from $234 to reach $271 by the third week of January. The rally, however, was short-lived and the palladium price faded during February, then plunged during March and early April as bids for metal dried up.

After hitting a low of $144, the price recovered to trade between $170 and $180 for much of the next three months. A rapid increase in speculative buying on NYMEX and TOCOM then provided the impetus for a second rally that peaked at $232 in September. However, the price eased during the fourth quarter to end the year at $193.

In early **January** 2003 the palladium price staged a robust recovery from its low of $222 the previous December as funds closed out approximately 80,000 oz of net short positions on NYMEX. At the same time, interest from industrial buyers picked up but offers of physical metal diminished. As a result, the spot price



climbed from an opening fixing of $234 to reach $267 on the 10th. This attracted increased volumes of metal back into the spot market and the price dipped to $242 on the 14th. A second rally then emerged as moderate fund buying (encouraged by labour problems at Norilsk Nickel) took the price up to a peak of $271 on the 22nd. However, whilst platinum continued to rise, the price of palladium then faltered in the face of heavy sales of physical metal on the London fixings and faded to end the month at $256.

The fundamental oversupply of palladium continued to weigh on the price during **February**. After initially moving up from $261 to $266 on the 4th the market subsided, with relatively small volumes of metal sufficient to move the price. By the 11th palladium had slipped below $250, then spent the next two weeks trading very quietly between $250 and $255. The market broke downward again on the 27th when large lots of metal were offered across the fixings, the price dropping to $243 as a result.

The palladium market was very subdued during the first half of **March**: the price traded within a $5 range around $240 through to the 12th. On the 13th the price slipped to $230 but then stabilised again for the next 10 days. On the 24th, however, the price entered a precipitous decline when offers of metal on the fixing met with no buying interest – the price slid to $216 before matching bids were found. The fall was exacerbated by stop-loss selling by dealers holding long physical positions. The slump continued on the 25th as palladium offered on the afternoon fixing found few bidders until the price dropped below $200. Moderate volumes of physical metal struggled to find buyers throughout the rest of the month, palladium ending March at $180.

The collapse in the palladium price continued into **April**, the metal sliding to $168 by the morning of the 8th. On the 14th an almost total absence of bids on the morning fixing resulted in a further drop to $161, the price slumped under $150 on the 16th, then hit $144 the following morning – a six year low. A muted rebound to $160 was seen following the Easter break, aided by a degree of fund buying on NYMEX and dealer short-covering. Physical demand, however, remained weak and palladium slipped back to trade either side of $150 for the rest of the month.

After falling by almost $100 during March and April the price of palladium stabilised during **May**, consolidating between $152 and $164 from the 1st through to the 19th. Fund interest in the metal then perked up, possibly on expectations of an upturn in purchasing by the automobile sector. With physical demand improving and dealer short-covering evident, the price climbed from $163 on the 19th to $206 on the 27th. The rally, however, then subsided under the weight of increased producer selling and palladium ended May at $183.

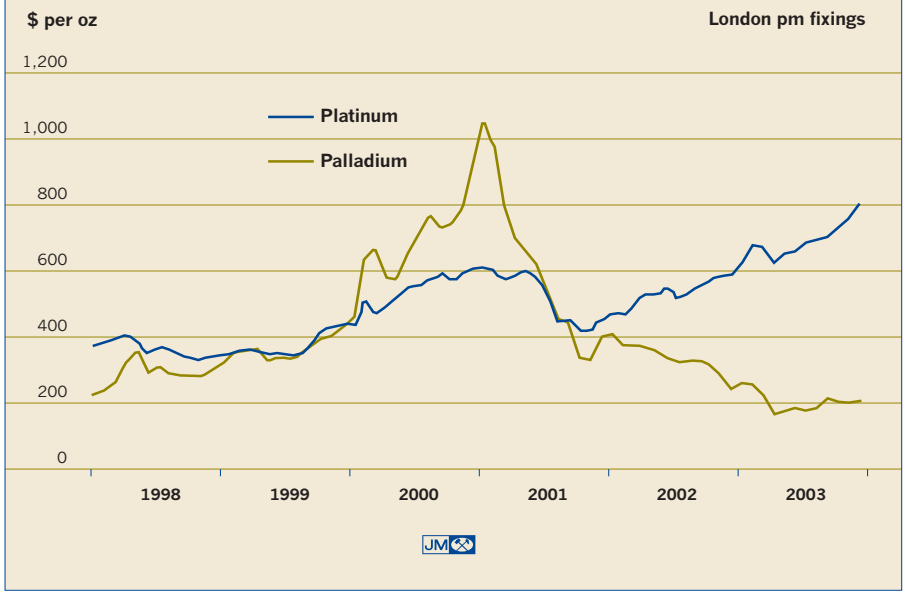
Palladium initially followed platinum upwards in **June**, rising to $190 on the 3rd before light selling pressure took the price down to just under $170 the following week. Steady fund buying of palladium on NYMEX then provided sufficient stimulus to push the price back up to $186 by the 16th; thereafter the price settled down into a narrow trading range, fixing between $173 and $179 for the rest of the month.

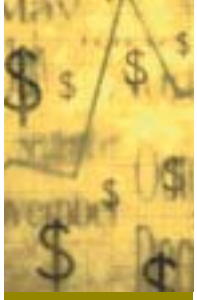
Further moderate fund buying of palladium on NYMEX lifted the price from $180 on the morning of the 1st of **July** to $188 on the afternoon of the 2nd in very thin trade. Fund interest in the metal then tailed off, cutting support from under the price. With physical demand deflated by the traditional summer slow-down, the price began to slide, following platinum downwards. Offers of metal found few buyers and the price dropped to $170 on the afternoon of the 9th. After pausing between $172 and $175 for several days the downward trend continued, the price softening to $160 by the 23rd. With volumes of both physical and futures trade thin, a slight upturn

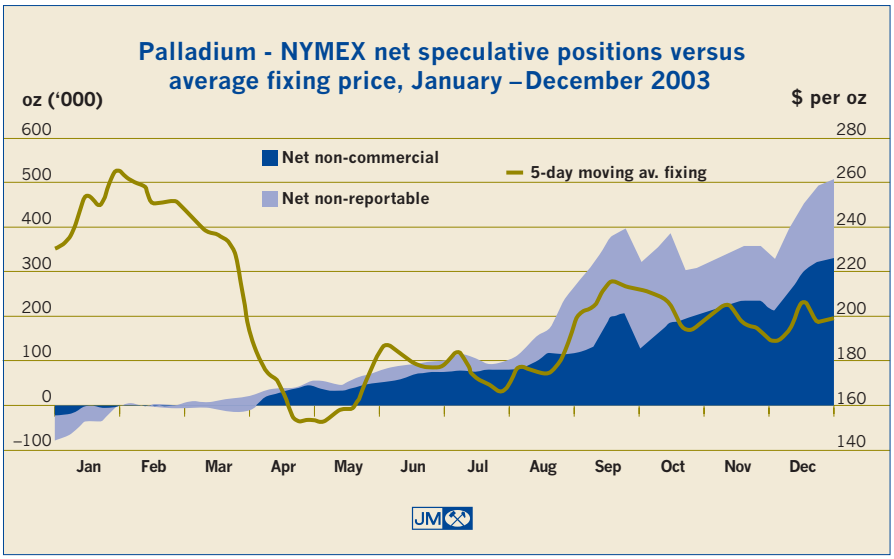
Palladium Prices in 2003
London am and pm fixings, $ per oz

	High	Low	Average
Jan	271.00	234.00	254.93
Feb	266.00	243.00	253.23
Mar	242.00	180.00	224.85
Apr	180.00	144.00	162.75
May	206.00	152.00	167.10
Jun	190.00	169.00	179.49
Jul	188.00	160.00	173.26
Aug	205.00	171.00	181.76
Sep	232.00	192.00	210.89
Oct	214.00	184.00	201.36
Nov	208.00	188.00	196.85
Dec	209.00	187.00	198.19

Platinum & Palladium Average Monthly Prices, 1998-2003







in activity on NYMEX then enabled the metal to recover to $178 by the end of the month.

Physical trade in palladium was light during the first half of **August** and the price floated between $170 and $180 from the 4th through to the 19th. On NYMEX, however, funds started steadily building on their existing net long positions of around 80,000 oz. This was reflected in the spot price from the 20th onwards as the volume of palladium futures traded on TOCOM also increased sharply. From a fixing of $176 on the 19th the price advanced swiftly to reach $205 on the 26th. The rally was then capped by strong physical sales but the price was supported above $200 by additional fund buying for much of the remainder of August. The net speculative long position on NYMEX tripled over the course of the month to approximately 240,000 oz.

Palladium continued to attract a strong degree of fund interest throughout **September**, the net speculative position on NYMEX reaching almost 400,000 oz, surpassing that of platinum. The fund buying of futures and options was sufficient to drive the palladium price from $199 on the 4th to $232 on the 9th. When the derivatives activity paused in mid-month, however, the price rapidly dropped under $200, there being insufficient physical demand to provide much support.

The dip triggered a resumption of fund buying of palladium derivatives on both NYMEX and TOCOM, which boosted the price to $219 on the 16th. The price then consolidated between $210 and $218 through to the 25th, but dipped again on the 26th as the platinum and gold markets slipped. This time, however, the palladium price held above $200 and the metal ended the month at $209.

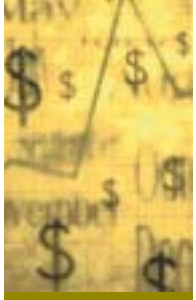
In early **October** the palladium price softened from around $210 towards $200 as good volumes of physical metal dampened the market. On the 14th a surge in offers of metal on the afternoon fixing sparked the start of several days of long liquidation as some funds switched from buying to selling. With no support from industrial purchasers of the metal the price slid under $200 on the morning of the 15th then to $184 on the afternoon of the 16th as stop-loss sell orders were triggered. The $20 drop in the palladium price in two days attracted fresh fund buying back into the market and the price subsequently staged a moderate recovery that peaked at $207 on the 30th.

Palladium traded uneventfully during the beginning of **November**, speculative buying being easily covered in the spot market, and the price held between $202 and $208 through to the 10th. The following day, long liquidation was seen from a single source and the morning fixing slipped to $199 as a result. The price weakened further on the 12th but then steadied and traded dully for the remainder of the month, ending with a fixing of $188.

Palladium managed to rally by $20 to reach $209 in early **December** on the back of further large buying of the metal by funds, primarily via NYMEX. This continued throughout the month, in contrast to the year-end profit-taking in platinum. However, despite the net speculative position increasing by 150,000 oz to over 500,000 oz on NYMEX over the course of the month, the physical market remained well supplied with metal. As bids for spot metal dried up towards the end of the year the palladium price drifted down, slipping to $193 on the 31st. This was almost 18 per cent below the year's opening fixing of $234 and a discount to platinum of $621.

Other pgm

In 2003 the rhodium price worked through the final phases of a decline dating back to 2000 (when it peaked at $2,600). After some moderate volatility during the first five months of the year, the market reached near equilibrium and the price stabilised at $500 as a result. Multi-year declines in the prices of ruthenium and iridium also came to an end in 2003 as industrial demand for the metals improved.



After falling rapidly at the end of 2002 due to the large volumes of metal offered to the market, the price of rhodium rebounded in January 2003 as enquiries increased and availability contracted sharply. The Johnson Matthey base price surged from $485 on the 7th to $650 on the 10th before limited selling came back into the market and the price eased to $620.

There was little further movement in the rhodium price until late February, when a sustained slide began that lasted through to the end of April. Demand from the key autocatalyst market was relatively soft, with vehicle production in the USA and Europe showing signs of slowing. Supplies of rhodium from South African producers, Russia, and secondary refiners were more than sufficient to meet market needs. As a result, the JM base price fell steadily from $600 at the beginning of March to $440 on the 28th April – its lowest level since February 1998.

During the final two days of April, however, the market began to turn. The swift fall below $450 stimulated increased buying interest and as the volume of bids increased the JM base price climbed back upwards during the first half of May, peaking at $590 on the 13th.

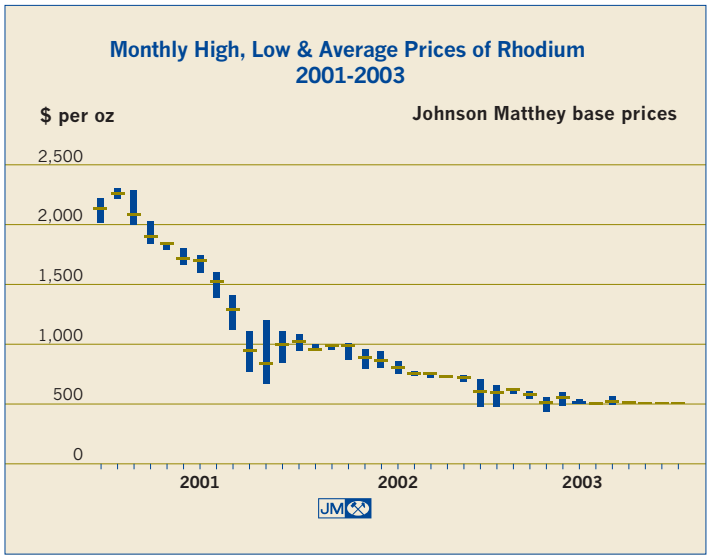
Again, however, the rally was capped by increased offers of metal and with the selling momentum outweighing purchasing interest from the auto industry the price subsided to settle at $500 on the 6th June. As the price dropped towards $500, offers of metal were scaled back and improved buying support emerged. The rhodium market subsequently moved more closely into balance and entered a sustained period of price stability for the first time since 1999. Apart from a brief rally to $560 in thin August trade, rhodium traded at, or very close to, $500 for the remainder of the year.

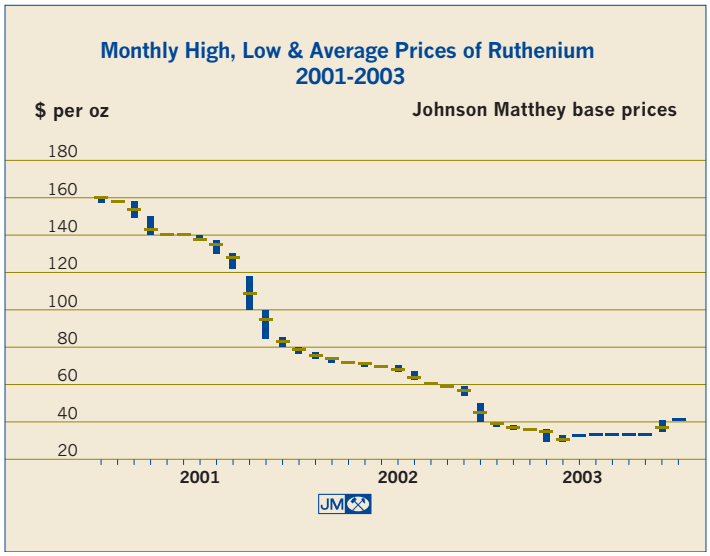
The Johnson Matthey ruthenium base price was marked steadily lower during the first four months of 2003, dropping from $40 at the beginning of January to a seven year low of $30 at the end of April as plentiful supply outweighed soft demand. The price then edged back up to $33 in May and stabilised at this level for the next five months.

In the final quarter of the year, improving demand in the electronics and industrial sectors finally fed through to the ruthenium price, which firmed from $33 at the end of October to $41 during November.

The Johnson Matthey iridium base price moved lower in line with the other minor pgm during January 2003, slipping from $125 at the start of the year to $100 by the middle of the month. The key electronics market for iridium crucibles showed signs of improving but primary supply remained in excess of demand and was supplemented by sales from the US National Defense Stockpile.

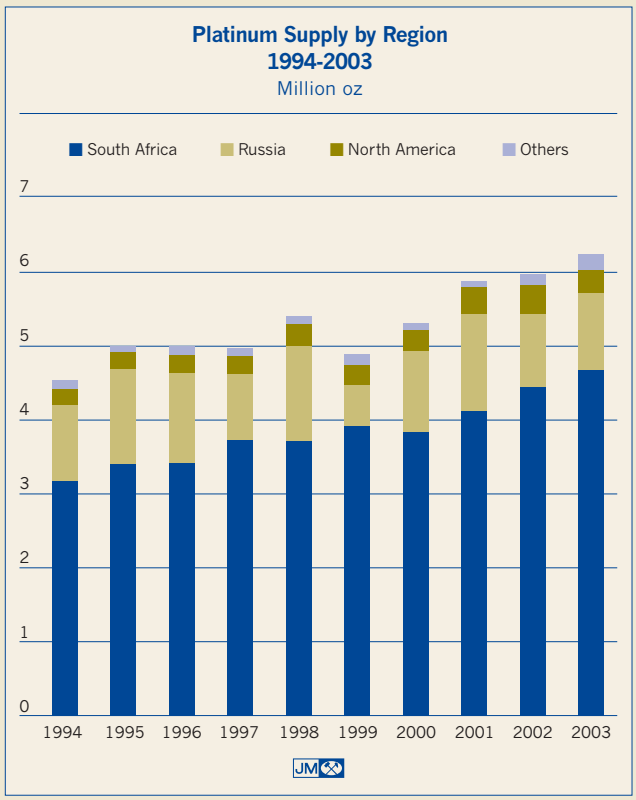
There was little activity in the iridium market until early April, when the price slipped by a further $10 to $90. As with rhodium and ruthenium, the market then appeared to reach equilibrium and the price remained unchanged through to the end of October. In contrast to ruthenium, however, the iridium price then softened again, edging down to $87 at the start of November. The price then remained unchanged for the rest of the year.

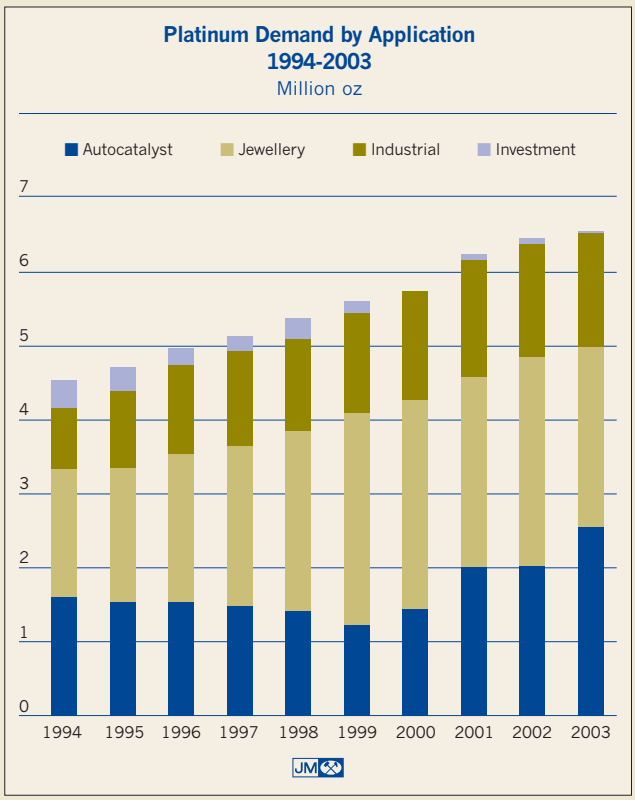




Platinum Supply and Demand

'000 oz	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Supply										
South Africa	3,160	3,370	3,390	3,700	3,680	3,900	3,800	4,100	4,450	**4,670**
Russia	1,010	1,280	1,220	900	1,300	540	1,100	1,300	980	**1,050**
North America	220	240	240	240	285	270	285	360	390	**295**
Others	140	100	130	120	135	160	105	100	150	**225**
Total Supply	**4,530**	**4,990**	**4,980**	**4,960**	**5,400**	**4,870**	**5,290**	**5,860**	**5,970**	**6,240**
Demand by Application										
Autocatalyst: gross	1,870	1,850	1,880	1,830	1,800	1,610	1,890	2,520	2,590	**3,190**
recovery	(290)	(320)	(350)	(370)	(405)	(420)	(470)	(530)	(565)	**(645)**
Chemical	195	225	230	235	280	320	295	290	325	**310**
Electrical	190	250	275	305	300	370	455	385	315	**340**
Glass	170	245	255	265	220	200	255	290	235	**175**
Investment: small	155	75	110	180	210	90	40	50	45	**30**
large	240	270	130	60	105	90	(100)	40	35	**(15)**
Jewellery	1,760	1,880	1,990	2,160	2,430	2,880	2,830	2,590	2,820	**2,440**
Petroleum	95	135	185	170	125	115	110	130	130	**150**
Other	195	230	255	295	305	335	375	465	540	**545**
Total Demand	**4,580**	**4,840**	**4,960**	**5,130**	**5,370**	**5,590**	**5,680**	**6,230**	**6,470**	**6,520**
Movements in Stocks	**(50)**	**150**	**20**	**(170)**	**30**	**(720)**	**(390)**	**(370)**	**(500)**	**(280)**



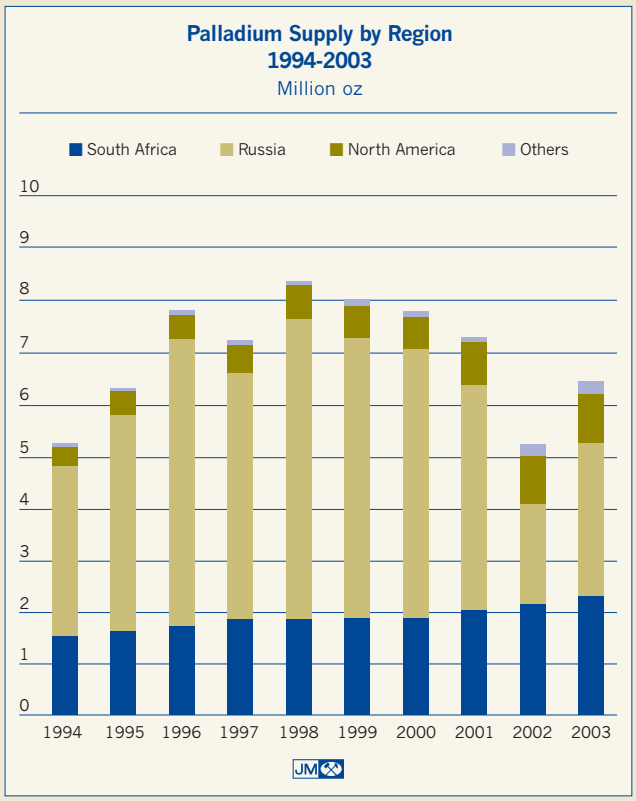


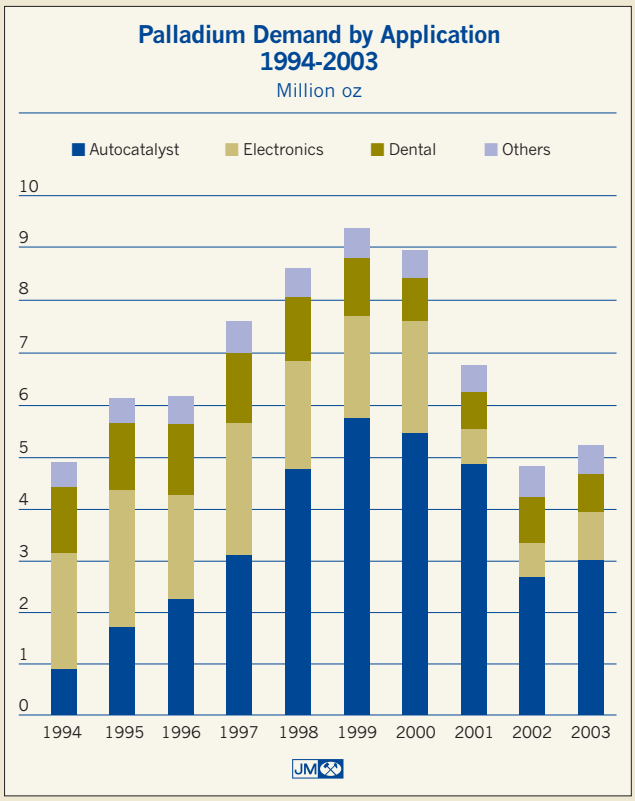
Platinum Demand by Application: Regions

'000 oz	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Europe										
Autocatalyst: gross	605	560	515	510	545	560	680	1,060	1,210	**1,340**
recovery	(10)	(15)	(20)	(25)	(30)	(30)	(40)	(70)	(90)	**(110)**
Chemical	50	55	60	70	60	80	100	105	115	**105**
Electrical	25	25	25	45	45	70	80	65	40	**45**
Glass	30	35	40	20	25	20	20	10	10	**10**
Investment: small	45	10	5	5	5	5	0	0	0	**0**
Jewellery	100	120	125	150	160	185	190	170	160	**170**
Petroleum	25	15	15	15	15	15	15	15	15	**15**
Other	65	75	75	85	85	90	105	155	190	**195**
Total	**935**	**880**	**840**	**875**	**910**	**995**	**1,150**	**1,510**	**1,650**	**1,770**
Japan										
Autocatalyst: gross	290	270	245	255	240	250	290	340	430	**510**
recovery	(45)	(40)	(50)	(50)	(55)	(60)	(60)	(55)	(55)	**(60)**
Chemical	15	20	20	20	20	20	20	25	30	**40**
Electrical	45	45	45	65	55	75	90	80	55	**60**
Glass	80	105	80	85	80	65	65	85	60	**50**
Investment: small	40	35	25	25	25	20	5	5	5	**5**
large	240	270	130	60	105	90	(100)	40	35	**(15)**
Jewellery	1,450	1,480	1,480	1,390	1,290	1,320	1,060	750	780	**665**
Petroleum	5	5	5	5	5	5	5	5	5	**5**
Other	25	25	25	30	30	35	35	35	55	**55**
Total	**2,145**	**2,215**	**2,005**	**1,885**	**1,795**	**1,820**	**1,410**	**1,310**	**1,400**	**1,315**
North America										
Autocatalyst: gross	790	820	850	800	775	535	620	795	570	**880**
recovery	(230)	(260)	(275)	(290)	(310)	(315)	(350)	(370)	(380)	**(425)**
Chemical	65	70	80	80	80	95	100	100	100	**90**
Electrical	75	115	130	100	105	120	145	120	100	**100**
Glass	20	25	30	45	20	25	50	35	30	**(5)**
Investment: small	65	25	75	145	175	60	35	45	40	**25**
Jewellery	55	65	90	160	270	330	380	280	310	**310**
Petroleum	5	40	60	50	40	40	35	40	45	**45**
Other	95	115	140	160	170	190	210	250	265	**265**
Total	**940**	**1,015**	**1,180**	**1,250**	**1,325**	**1,080**	**1,225**	**1,295**	**1,080**	**1,285**
Rest of the World										
Autocatalyst: gross	185	200	270	265	240	265	300	325	380	**460**
recovery	(5)	(5)	(5)	(5)	(10)	(15)	(20)	(35)	(40)	**(50)**
Chemical	65	80	70	65	120	125	75	60	80	**75**
Electrical	45	65	75	95	95	105	140	120	120	**135**
Glass	40	80	105	115	95	90	120	160	135	**120**
Investment: small	5	5	5	5	5	5	0	0	0	**0**
Jewellery	155	215	295	460	710	1,045	1,200	1,390	1,570	**1,295**
Petroleum	60	75	105	100	65	55	55	70	65	**85**
Other	10	15	15	20	20	20	25	25	30	**30**
Total	**560**	**730**	**935**	**1,120**	**1,340**	**1,695**	**1,895**	**2,115**	**2,340**	**2,150**

Palladium Supply and Demand

'000 oz	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Supply										
South Africa	1,500	1,600	1,690	1,810	1,820	1,870	1,860	2,010	2,160	**2,310**
Russia	3,300	4,200	5,600	4,800	5,800	5,400	5,200	4,340	1,930	**2,950**
North America	410	470	455	545	660	630	635	850	990	**940**
Others	70	70	95	95	120	160	105	120	170	**250**
Total Supply	**5,280**	**6,340**	**7,840**	**7,250**	**8,400**	**8,060**	**7,800**	**7,320**	**5,250**	**6,450**
Demand by Application										
Autocatalyst: gross	975	1,800	2,360	3,200	4,890	5,880	5,640	5,090	3,050	**3,460**
recovery	(105)	(110)	(145)	(160)	(175)	(195)	(230)	(280)	(370)	**(410)**
Chemical	185	210	240	240	230	240	255	250	255	**250**
Dental	1,265	1,290	1,320	1,350	1,230	1,110	820	725	785	**725**
Electronics	2,230	2,620	2,020	2,550	2,075	1,990	2,160	670	760	**895**
Jewellery	205	200	215	260	235	235	255	230	260	**250**
Other	115	110	140	140	115	110	60	65	90	**90**
Total Demand	**4,870**	**6,120**	**6,150**	**7,580**	**8,600**	**9,370**	**8,960**	**6,750**	**4,830**	**5,260**
Movements in Stocks	**410**	**220**	**1,690**	**(330)**	**(200)**	**(1,310)**	**(1,160)**	**570**	**420**	**1,190**





Palladium Demand by Application: Regions

'000 oz	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Europe										
Autocatalyst: gross	260	650	860	1,100	1,370	1,530	1,900	1,730	1,370	**1,210**
recovery	0	0	(5)	(5)	(5)	(10)	(15)	(30)	(45)	**(70)**
Chemical	60	65	65	70	65	65	95	65	70	**65**
Dental	255	250	255	260	210	180	100	50	55	**70**
Electronics	255	325	300	340	270	255	265	35	85	**85**
Jewellery	30	30	30	50	50	50	45	35	35	**35**
Other	25	20	20	25	25	25	20	20	15	**20**
Total	**885**	**1,340**	**1,525**	**1,840**	**1,985**	**2,095**	**2,410**	**1,905**	**1,585**	**1,415**
Japan										
Autocatalyst: gross	125	145	180	245	480	600	510	505	520	**540**
recovery	(30)	(25)	(30)	(45)	(50)	(55)	(50)	(40)	(40)	**(40)**
Chemical	20	20	20	20	20	20	20	20	20	**20**
Dental	550	580	600	620	590	545	470	475	505	**405**
Electronics	1,400	1,600	990	1,390	1,060	980	990	260	140	**220**
Jewellery	120	115	115	110	105	105	150	140	165	**160**
Other	15	10	10	10	10	10	15	10	10	**10**
Total	**2,200**	**2,445**	**1,885**	**2,350**	**2,215**	**2,205**	**2,105**	**1,370**	**1,320**	**1,315**
North America										
Autocatalyst: gross	525	950	1,230	1,680	2,820	3,490	2,805	2,375	640	**1,210**
recovery	(75)	(85)	(110)	(105)	(115)	(125)	(155)	(200)	(260)	**(270)**
Chemical	60	70	70	70	70	75	65	75	75	**70**
Dental	410	410	410	415	390	350	230	190	215	**235**
Electronics	450	545	490	550	460	405	485	250	210	**215**
Jewellery	5	5	5	10	10	10	10	0	0	**0**
Other	55	65	90	55	55	50	5	15	45	**40**
Total	**1,430**	**1,960**	**2,185**	**2,675**	**3,690**	**4,255**	**3,445**	**2,705**	**925**	**1,500**
Rest of the World										
Autocatalyst: gross	65	55	90	175	220	260	425	480	520	**500**
recovery	0	0	0	(5)	(5)	(5)	(10)	(10)	(25)	**(30)**
Chemical	45	55	85	80	75	80	75	90	90	**95**
Dental	50	50	55	55	40	35	20	10	10	**15**
Electronics	125	150	240	270	285	350	420	125	325	**375**
Jewellery	50	50	65	90	70	70	50	55	60	**55**
Other	20	15	20	50	25	25	20	20	20	**20**
Total	**355**	**375**	**555**	**715**	**710**	**815**	**1,000**	**770**	**1,000**	**1,030**

Rhodium Supply and Demand

'000 oz	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Supply										
South Africa	330	342	359	377	400	410	457	452	490	**545**
Russia	80	80	110	240	110	65	290	125	90	**140**
North America	15	13	5	16	16	18	17	23	25	**20**
Others	1	1	2	3	4	8	3	4	10	**15**
Total Supply	**426**	**436**	**476**	**636**	**530**	**501**	**767**	**604**	**615**	**720**
Demand by Application										
Autocatalyst: gross	379	464	424	418	483	509	793	566	599	**665**
recovery	(34)	(37)	(45)	(49)	(57)	(65)	(79)	(88)	(99)	**(123)**
Chemical	10	13	21	36	31	34	39	44	39	**37**
Electrical	8	8	9	9	6	6	7	6	6	**6**
Glass	14	17	53	43	34	35	42	41	37	**31**
Other	11	9	9	10	10	9	10	10	10	**11**
Total Demand	**388**	**474**	**471**	**467**	**507**	**528**	**812**	**579**	**592**	**627**
Movements in Stocks	**38**	**(38)**	**5**	**169**	**23**	**(27)**	**(45)**	**25**	**23**	**93**

Notes to tables

Supply figures are estimates of sales by the mines of primary pgm.

With the exception of the autocatalyst sector, **demand** estimates are net figures, demand in each sector being total purchases by consuming industries less any sales back to the market. Thus, annual totals represent the amount of primary metal that is acquired by consumers in a particular year. We continue to exclude the CIS from our demand estimates.

Movements in stocks in a given year reflect changes in stocks held by fabricators, dealers, banks and depositories but excluding stocks held by primary refiners and final consumers. A positive figure indicates an increase in stocks; a negative figure indicates a rundown in stocks.

Gross autocatalyst demand is purchases of pgm by the auto industry for manufacture of catalytic converters. **Autocatalyst recovery** is pgm recovered from scrapped catalytic converters and is allocated to the region in which the converter was scrapped.

Investment: small refers to the long-term holding of metal in the form of coins, and bars weighing 10 oz or less. **Investment: large** is in the form of 500 g and 1 kg bars in Japan and includes platinum held on account for subscribers to accumulation plans.

Glossary

g	grams
kg	kilograms
tonne	1,000 kg
tons	short tons (2,000 pounds or 907 kg)
oz	ounces troy
pgm	platinum group metals
ppt	parts per thousand
prices	all prices quoted are per oz unless otherwise stated
R	South African rand
$	US dollars
¥	Japanese yen
Almaz	Almazjuvelirexport, the pgm marketing agency of the Russian Federation
BEE	Black Economic Empowerment
CO	carbon monoxide
GDP	gross domestic product
HC	hydrocarbons
HIC	hybrid integrated circuit
LCD	liquid crystal display
LEV	Low Emissions Vehicle
Merensky, UG2, Platreef	platiniferous orebodies in South Africa
MLCC	multi-layer ceramic capacitor
NOx	oxides of nitrogen
NYMEX	New York Mercantile Exchange
PEM	proton exchange membrane
PM	particulate matter
TOCOM	Tokyo Commodity Exchange
ULEV	Ultra Low Emissions Vehicle
ZEV	Zero Emissions Vehicle

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