

https://dspace.org/

The platinum market: fundamentals affecting supply and demand

Mauve, Anton Christopher

2014-05-22
http://hdl.handle.net10539/14702

Downloaded from a DSpace repository. https://dspace.org/

THE PLATINUM MARKET

FUNDAMENTALS

AFFECTING SUPPLY AND DEMAND

Anton Christopher Mauve

A project report submitted to the Faculty of Engineering, University of the Witwatersrand in partial fulfillment of the requirements for the degree of Master of Science in Mining Engineering

Rustenburg, 2000

DECLARATION

I declare that this project report is my own, unaided work. It is being submitted in partial fulfillment of the Degree of Master in Science in Mining Engineering at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

A. C. MAUVE

11th DAY OF April 2000.

ABSTRACT

The platinum market is best understood through a comprehensive analysis of supply and demand. Supply is most significantly affected by production constraints and the erratic draw-down in Russian stockpiles. Total world supply of platinum for 1998 amounted to 5.915 Moz, 64% of which was produced from the Bushveld Complex in South Africa. The remainder emanated from Russia, Zimbabwe, the United States, Canada and the recycling of autocatalysts. Supply is forecast to drop by 320 000 oz in 1999 due to a lower Russian export quota and reduced Zimbabwean production.

Demand for platinum is unusual, in that it is sought after both as a store of wealth, and has properties that make it irreplaceable in a host of industrial applications. Current world demand for the metal is driven by a growing Eastern jewelry market and increased use in autocatalysts due to vehicle emissions legislation. Total world demand for 1998 amounted to 5.755 Moz. A predicted steady growth in the consumption of platinum for jewelry and existing applications, together with development of new uses, is expected to result in an annual 250 000 oz increase in demand for 1999 and 2000.

The derived supply and demand balance for 1998 shows a small excess in supply relative to demand. This will be absorbed by inventories and is likely to have little affect on price. A significant shortfall of 410 000 oz, however, is predicted for 1999. This is likely to be followed by a further shortfall in 2000 and will drive up prices, impel consumers towards substitution and thrifting and encourage producers to expand.

In memory of my Grandfather

J R C Lawrence

1915 - 2000

ACKNOWLEDGMENTS

The author would like to express appreciation to Lonmin Platinum for the use of facilities and financial assistance.

Dr. R.C.A. Minnitt and Miss. J.D. Marland are to be thanked for providing assistance and advice in the preparation of the report.

CONTENTS **Page**

DECLARATION		ii
ABSTRACT		iii
DEDICATION		iv
ACKNOWLEDGMENTS		v
CONTENTS		vi
LIST OF FIGURES		ix
LIST OF TABLES		x
LIST OF SYMBOLS		xii
LIST OF ABBREVIATIONS		xiii
1	**INTRODUCTION**	**1**
2	**PRINCIPLES OF SUPPLY AND DEMAND**	**3**
2.1	Supply	3
2.2	Demand	4
2.3	Use of Demand and Supply Estimation in this Study	5
3	**UNIQUE PROPERTIES AND SPECIFIC USES**	**7**
3.1	Properties of Platinum	7
3.2	Specific Uses for Platinum	8
3.3	New Uses for Platinum	14
3.4	Summary	16
4	**THE EFFECT OF LEGISLATION**	**18**
4.1	The World Vehicle Parc	18
4.2	Impact of Air Pollution on Health	19
4.3	Emissions Legislation	19
4.4	Effect of Emissions Control on Demand for Platinum	24
4.5	Summary	27

CONTENTS Page

5	**THE PLATINUM JEWELRY AND INVESTMENT MARKET**	**29**
5.1	Jewelry	29
5.2	Investment	38
5.3	Summary	42
6	**RUSSIAN PLATINUM SUPPLY**	**44**
6.1	Russian Resources	45
6.2	Annual Production	46
6.3	Double Accounting	49
6.4	Stockpiles	49
6.5	Government Strategies	50
6.6	Summary	51
7	**FACTORS AFFECTING PLATINUM PRODUCTION**	**53**
7.1	Cost	53
7.2	Legislation	57
7.3	Technical Advancement	58
7.4	Platinum as a Main-Product or By-Product	59
7.5	Labour	60
7.6	Political Stability	61
7.7	Exploitation of Reserves	61
7.8	Production "Bottle-necks"	62
7.9	Summary	63
8	**WORLD PLATINUM SUPPLY**	**64**
8.1	World Resources	64
8.2	Current Supply	77
8.3	Future Supply	88
8.4	Summary	95

CONTENTS Page

9	**WORLD PLATINUM DEMAND**	**97**
9.1	The Platinum Product	97
9.2	Current Demand for Platinum by Application	97
9.3	Current Platinum Consumption by Region	108
9.4	Estimated Future Platinum Demand	110
9.5	Summary	112
10	**BALANCE OF SUPPLY AND DEMAND**	**114**
10.1	Current World Supply and Demand Estimates	114
10.2	Future Total Supply and Demand Predictions	115
10.3	Deriving a Supply and Demand Balance	116
10.4	Analysis of the Balance	118
10.5	Prediction of Price	120
11	**SUMMARY**	**121**
11.1	Understanding the "Critical Factors" Affecting Supply and Demand	121
11.2	The Platinum Supply and Demand Balance	125
12	**CONCLUSION**	**126**
12.1	Further Work	127
APPENDIX		**128**
REFERENCES		**129**

LIST OF FIGURES

FIGURE		Page
4.1	World PGM demand for autocatalysts	26
5.1	The variation in the platinum and gold share of the Japanese jewelry market	35
5.2	World demand for platinum in jewelry	37
6.1	Variability of Russian supply	45
6.2	A comparison of the production-supply routes followed by Russia and other producing countries	50
7.1	An estimated cost curve for major primary product platinum producers	55
7.2	"Bottle-necks" in the production of platinum	62
8.1	The geographic distribution of significant world platinum resources	66
8.2	The distribution of known world resources of platinum	76
8.3	Average individual PGM percentages in known world resources	76
8.4	South African platinum producers in the Bushveld Complex	80
8.5	Recovery of platinum from autocatalysts	86
8.6	Increase in world supply 1988 to 1998	87
9.1	Share of platinum demanded by applications	98
9.2	Growth in platinum demand 1988 to 1998	109

LIST OF TABLES

Table		Page
3.1	Properties of platinum	8
4.1	United States federal and low emissions vehicles standards	21
4.2	European emissions limits for petrol driven passenger vehicles	22
4.3	Japanese emissions limits for petrol driven passenger vehicles	23
4.4	A forecast of autocatalyst equipped vehicles in the global parc, by 2000	24
5.1	Strategies and results of PGI marketing prior to 1999	33
6.1	Severity of conditions at Norilsk	47
7.1	Increase and loss of precious metal grade during each stage of PGM ore processing	57
7.2	A hypothetical matte evaluation	60
8.1	Proportion platinum of PGM for reef types and regions within the Bushveld Complex	67
8.2	Platinum resources in the Norilsk and Talnakh deposits, Russia	69
8.3	Calculated resources of platinum for the Main Sulphide Zone within regions of the Great Dyke	70
8.4	Resources of PGM within the USA	72
8.5	Resources of PGM in Canada's Sudbury Basin and Lac des Isles Deposits	73
8.6	Other resources of PGM, which support mining activities	75
8.7	Estimated *in situ* world resources of platinum	75
8.8	Current South African platinum production	79
8.9	Current Russian platinum production	81
8.10	Current Zimbabwean platinum production	82
8.11	Current North American platinum production	83
8.12	Estimated current world platinum supply	87
8.13	Estimated increase or drop in world platinum supply year on year	95
9.1	Annual demand for platinum in production of autocatalysts	99

Table		Page
9.2	Annual demand for platinum in jewelry	101
9.3	Annual demand for platinum in chemical manufacture	102
9.4	Annual demand for platinum in the electronics industry	103
9.5	Annual demand for platinum in glass manufacture	104
9.6	Annual demand for platinum as a means of investment	105
9.7	Annual demand for platinum in petroleum refining	106
9.8	Annual demand for platinum in other uses	107
9.9	Total annual demand for platinum by applications	108
9.10	Total annual demand for platinum by region	109
10.1	Estimated supply and demand balance	117

LIST OF SYMBOLS

Symbol	Meaning
%	percentage
$	dollar
(000)	thousand

LIST OF ABBREVIATIONS

Abbreviation	Meaning
Au	gold
BC	Bushveld Complex
BC*	(of date) before Christ
°C	degrees Celsius
cm^2	square centimetres
cm^3	cubic centimetres
CO	carbon monoxide
CO_2	carbon dioxide
Co	cobalt
Ct	carat
Cu	copper
D	density
DMS	Dense Media Separation
EC	European Community
EU	European Union
EV	electrically powered vehicle
Fe	iron
g	gram
g/km	grams per kilometre
g/m	grams per mile
g/t	grams per ton
GDP	Gross Domestic Product
H_2	hydrogen gas
HC	hydrocarbon
HIV	human immunodeficiency virus
H_2O	water
Ir	iridium
Ito	in terms of
IU	Intensity of Use

kg	kilogram
Lb	pound (weight)
LEV	low emissions vehicles
LCD	liquid crystal display
LDI	Lac des Isles
Mlb	million pounds (weight)
Moz	million ounces
My	million years
N_2	nitrogen gas
NAP	North American Palladium
Ni	nickel
NLEV	new low emissions vehicle
NYMEX	New York Mercantile Exchange
OBD	on-board diagnostic
O_2	oxygen gas
Os	osmium
oz	ounce (31.1035g)
PAP	Platinum Accumulation Programme
Parc	population (of vehicles)
PC	personal computer
Pd	palladium
PEM	proton exchange membrane
PGI	Platinum Guild International
PGM	platinum group metal
PGM+Au	All platinum group metals and gold
3PGM+Au	platinum, palladium, rhodium and gold
PM	particulate matter
ppm	parts per million
Pt	platinum
Rh	rhodium
Ru	ruthenium
S	sulphur
SA	South Africa

SULEV	super ultra-low emissions vehicle
t	ton
TKK	Tanaka Kikinzoku Kogyo
UBS	Union Bank of Switzerland
UG2	Upper Group Two Chromitite Layer
ULEV	ultra-low emissions vehicle
US	United States
USA	United States of America
VRT	virgin rock temperature
ZEV	zero emissions vehicle

1 INTRODUCTION

This project investigates factors which are crucial to the supply and demand of platinum. An understanding of these factors is of primary importance to correct estimation of current and future world supply and demand. Accurate estimations allow analysts to determine whether there is an excess or shortfall, in available metal, in any particular year. This study sets out to provide an estimated supply and demand balance for 1998 and a predicted balance for 1999 and 2000. These balances are used as a tool for an assessment of the market and predictions of price trend.

Future price trend is most important to platinum producers and consumers. An expected increase in the price of the commodity, for example, would encourage producers to expand operations and consumers to thrift and look for substitutes. This study sets out to provide a "fundamentalist" approach to price prediction. A "theoretical" approach involving a study of commodity cycles and forward markets is not considered in this work, but would compliment it, and assist in a thorough understanding of the market.

Principles of supply and demand for mineral commodities are briefly discussed in chapter 2. This chapter provides a review of existing methods of supply and demand estimation. Factors which most critically affect the current demand and supply of platinum are discussed individually in chapters 3, 4, 5 ,6 and 7. These factors are; unique properties and specific uses, effect of legislation, the jewelry market, Russian supply and constraints on production, respectively. Chapters 8 and 9 provide current and future estimates of all platinum supplied and demanded. A current and predicted supply and demand balance is presented and discussed in chapter 10.

Platinum is a precious metal which is currently valued for both its rarity and its properties. It has been traded as a commodity for over two hundred years, but has only recently been recognized for its unique nature. While early use was limited to jewelry, it is currently sought after for a wide diversity of industrial and investment applications. Analyses of the platinum market are undertaken on a regular basis to assist consumers and producers in making strategic business decisions. These analyses, usually focus on estimated figures and have traditionally failed to provide a thorough understanding of the unique nature of the commodity and its supply and demand. Such an understanding is of paramount importance to an accurate supply and demand balance prediction.

Most supply and demand data used in this study is gleaned from Market Reports, Annual Reports of producers and current news articles on the subject. A large contribution of material was sourced from Johnson Matthey annual reports, the internet, the 1998 World Platinum Conference and in personal communication. The book, "The Platinum-Group Metals - A Global Perspective" by C. F. Vermaak, has provided an excellent reference for aspects of platinum supply and historical demand development.

All conclusions made in this report are based on the current state of the platinum market. The word "current" refers to events of the year 1998.

2 PRINCIPLES OF SUPPLY AND DEMAND

The following chapter is aimed at clarifying the concept of supply and demand, as applied in this report. Factors which both drive and moderate supply and demand for mineral commodities are listed. A brief explanation is given of methods of deriving an estimation of world supply and demand for a commodity.

2.1 Supply

Supply (as used in this report) is defined as "the provision of a commodity". Tilton (1985) lists the following factors which drive supply for most mineral commodities:

1) The price of the commodity.
2) The status of the commodity
3) Input costs
4) Socio-political disruptions
5) The structure of the market
6) Technological change
7) Governmental activities

An analyst must recognize the effect that each of these factors has on availability.

Total world supply for a commodity is estimated by calculating the total amount of that commodity made available to the market. Mineral commodities are made available from primary production (which generates; individual products, main products, co-products and by-products) and secondary production, of new and old scrap*. Figures for both primary and secondary production can be acquired from annual reports of producers.

*In the case of the platinum market, metal made available from Russian stockpiles is also considered supply, as it represents an extensive source. All other inventory depletion's are treated as "changes in inventories" and accounted for in demand.

Such data should be audited and must be verified to ensure the accuracy of a supply estimation. Supply can be measured at each stage of the production process of a commodity (e.g..; comminution, concentration, refining and scrap metal recovery).

2.2 Demand

Demand (as used in this report) is defined as "the desire that a consumer has for a commodity". Tilton (1985) lists the following factors which drive demand for most mineral commodities:

1) The price of the commodity.
2) Income (GDP).
3) The availability of substitutes for a commodity.
4) The availability of complimentary substances which can be used in combination with a commodity.
5) Consumer preferences.
6) Technological change.
7) Governmental Activities.

An understanding of these factors is critical to an analysis and prediction of demand for a commodity.

Demand can be measured and analysed at different stages of use. Platinum demand, for example can be measured during the following stages of beneficiation:

1. **Fabrication** of refined platinum and platinum products.
2. **Manufacturing** of platinum products (i.e..; Mints, Autocatalyst Producers, Jewelry manufacturers etc.).
3. **Consumption** of final platinum products.

Radetzki and Tilton (1988), suggest four techniques for estimating the demand for a mineral commodity. These are:

1. The Intensity of Use (IU) technique which calculates the demand for a commodity based on its use in all final products.
2. Demand for a commodity as a relationship of its determinants. This technique suggests that demand for a commodity is a function of its price, the price of its close substitutes and GDP.
3. Demand based on one specific application of a commodity. An example of this is the estimation of total world copper demand based on its use in the manufacture of insulated cable.
4. The use of input-output tables. This technique requires that input-output tables are sufficiently disaggregated to allow an analyst to identify the individual commodity and determine its intermediate and final uses.

Two factors are critical when estimating annual world demand for a commodity, viz;
1. Data used must be validated. The higher the quality of the data used the more accurate the estimation of demand.
2. Changes in inventory must be accounted for. This is a difficult task due to the general lack of reporting on inventories. It is important to remember that quantities demanded by inventories must be negative in order to compensate for shortfalls in supply.

2.3 Use of Demand and Supply Estimation in this Study

Information pertaining to annual estimates of supply and demand for commodities is available from a number of sources. Actual observation, internet web sites, news reports and annual reports of producers and consumers are the most current and relevant sources for such data. Once data has been sourced it must be verified and validated before it can be used with any degree of confidence. The higher the degree of accuracy of all data which constitutes total world supply or demand for a commodity, the greater the confidence in a prediction of the state of the market.

Once the underlying factors that affect supply and demand of a commodity have been well researched (sourced and validated), a supply and demand balance can be worked out. This balance can be calculated for historic, current and future commodity markets. A derived excess or shortfall in future supply (within the "balance") will assist analysts in their predictions of commodity prices.

These notes on supply and demand are applicable to the average mineral commodity. The following chapters will concentrate on supply and demand fundamentals applicable to platinum market predictions. A number of supply and demand factors are considered critical to the current market for platinum, and are assigned separate chapters.

3 UNIQUE PROPERTIES AND DIVERSITY OF USES

Platinum is a commodity with unique properties which are sought after by consumers for the manufacture of a vast number of specific products. Its properties are, in fact, so unique that it is irreplaceable in certain applications. These properties are therefore a significant factor in driving demand for the metal. This is particularly true for industries that cannot thrift or find a substitute for platinum. Vermaak (1995) notes that the commercial substitution of platinum by "cheaper metals" is exceedingly rare. Demand for platinum is further driven by the increasing number of new uses being discovered. This chapter examines the properties of platinum and looks at specific applications that rely on these properties. New uses for platinum are also reviewed.

3.1 Properties of Platinum

It has a high resistance to oxidation and corrosion, and is classified as a noble metal (together with the other platinum group metals, gold and silver). Because of the scarcity of platinum in the earths lithosphere it is also classed as a precious metal. It's molecular weight (almost twice that of lead), unusually high melting point and extreme durability are useful in "high temperature, high pressure production" (Swiss America, 1999). It is chemically inert to a wide variety of elements and compounds, even at high temperatures. In addition, it is highly conductive and therefore ideal for applications in high-tech sensors. Perhaps the most important property of platinum is its ability to c cken chemical processes as a catalyst. Dobereiner observed the first platinum-catalysed reaction of H_2 and O_2 to produce H_2O, in 1821 (Okafor and Coville,1999). The most famous catalytical reaction, involving platinum, is the conversion of methane to its oxygenates without proceeding via CO or CO_2. The current extent of platinum's use in catalysis is illustrated by the fact that the 1996 Journal of Catalysis contained 90 papers on the subject (Okafor and Coville,

1999). The most well used catalytic reactions involving platinum are; environmental catalysis and petroleum reforming catalysis. The properties of platinum are summarised in Table 3.1 below.

Table 3.1 Properties of platinum (after Vermaak, 1995)

LITHOSPHERIC ABUNDANCE	0,005 ppm (extremely rare)
CORROSIVENESS	Non-corrosive
RESISTANCE TO CHEMICAL ATTACK	Highly resistant
HARDNESS	4,3 (Harder than gold and softer than silver) Ductile and malleable
MELTING POINT	1768^{0}C (extremely high, not easily fused or cast)
TENSILE STRENGTH	High
ELECTRICAL CONDUCTIVITY	Low
COEFFICIENT OF EXPANSION	Lowest of all commercial metals
RELATIVE DENSITY	2,145 (Heavy)
LUSTRE	Silvery white

3.2 Specific Uses for Platinum

Manufacturers rely on platinum's properties for a wide diversity of specific and irreplaceable industrial uses. It is used predominantly in the autocatalyst, chemical, electrical, glass and petroleum industries. In addition, to well documented uses in these industries, it is being used in an increasing number of "other" applications. These include; neurosurgical and dental apparatus, drugs for cancer treatment, on-board diagnostic systems in vehicles and spark plugs. It is suggested that the use of platinum is so diverse in modern day society, that one in five goods manufactured either contains or is produced using platinum (Swiss America, 1999). Because it is an essential metal in terms of its use in various defense, medical and telecommunications industries, the US Government has classified it as a "strategic metal". It is stockpiled in the

USA for possible defense emergencies. The following is a brief description of the most important applications that rely on the properties of platinum.

3.2.1 Autocatalysts

The principle industrial use for platinum is as an alloy in auto-catalysts. Autocatalysts are used to convert harmful emissions of CO, NOx and HC into the relatively inert compounds of CO_2, H_2O and N_2 (Young, 1998). There are two main types of autocatalysts. Firstly, an oxidizing Pt/Pd catalyst which converts CO and HC to CO_2 and H_2O. This system uses a PGM loading of 50% Pt and 50% Pd. Secondly, a more modern "three-way" or Lambda Sond system that can, in addition, reduce NOx to N_2. Young (1998) reports that three-way catalysts currently contain either Pt-Pd-Rh alloys, Pt-Rh alloys, Pd-Rh alloys or Pd only. A typical autocatalyst consists of three parts; a support substrate, a washcoat and the appropriate PGM catalyst (Vermaak, 1995). The most commonly used substrate is a honeycomb structured ceramic monolith (or brick). This monolith has a cylindrical shape and can be either circular or elliptical in cross-section. It is usually constructed of a porous ceramic substance (cordierite). The walls of the monclith are commonly 0.15 mm thick and contain about 60 holes per cm^2. An alumina washcoat is added to the substrate to increase high temperature resistance. After the additions of nickel and certain rare earth elements to the alumina washcoat, the substrate is fired. The final surface area, covered by the washcoat is estimated to be about $100m^2$ (Vermaak, 1995). After firing a PGM solution is applied to the surface providing the active catalytic layer. The finished autocatalyst is then insulated by wire mesh and fibre matting and is mounted inside a stainless steel canister. This autocatalytical convertor is installed ahead of the silencer in a vehicles exhaust train.
Although autocatalysts must contain PGM in order to be effective in emissions control, substitution of one PGM for another can occur. The composition of the loadings of PGM's is thus largely dependent on the

individual prices of the metals. Johnson Matthey (1999) report that there is a current trend for substitution of platinum by palladium in autocatalysts for petrol driven vehicles (due to the cheaper cost of pd). This is, however, offset by the required use of platinum in autocatalysts of diesel powered vehicles. Each new PGM alloy designed, requires patenting and testing prior to implementation. This delays the manufacturers ability to react immediately to price changes. Most large manufacturers make use of strategic inventories of the required PGM's to overcome such problems. Although automanufacturers are continuously involved in attempts to "thrift" on the use of expensive PGM's, sticter emissions standards continually demand increased loadings. The loadings of autocatalysts are discussed in more detail in the following chapter.

3.2.2 Chemical uses

Platinum's chief use in the chemical industry is as a process catalyst, particularly in the production of nitric acid, benzine and silicons. It is used as a woven or knitted gauze in the production of nitric acid. This chemical is required in the manufacture of fertilizers and explosives. Increase in demand for platinum is thus closely related to increase in agricultural production and mining. Johnson Matthey (1999) report that the European Union is currently intent on limiting the build-up of grain stocks. This is expected to reduce the demand for fertilizers (and therefore platinum in this application) in 1999. There is currently a large Middle Eastern demand for platinum in the production of benzine (Johnson Matthey, 1999). This industry makes use of a platinum catalyst to maximise the output of benzine while limiting the production of other less valuable aromatic chemicals. A large quantity of platinum is used in the manufacture of silicones for adhesives and sealants. There is currently a large demand for these products in the construction industries of North America and Europe.

Vermaak (1995), reports the following additional chemical industry applications for platinum;

- The construction of laboratory ware
- The manufacture of sulfuric acid and hydrogen cyanide
- As an electrode in the water purification process
- The production of polyester films and fibres
- The leaching of gold from it's ore

3.2.3 Electrical uses

Platinum's principle electrical application is in hard discs for personal computers (Johnson Matthey, 1999). As computer technology and sales increases, so the need to improve the data storage capacity of hard discs increases. Johnson Matthey (1999) report that personal computer sales, worldwide have increased four-fold since 1990. Further increase in personal computer (PC) sales is expected to see demand for platinum, in hard discs, double by 2002. A typical modern PC is capable of storing 4 gigabytes of data on two to three hard discs. Each disc is only 3.5 inches in diameter. A typical hard disc consists of a substrate and a number of coated layers. The substrate is usually aluminium in desk top computers and high-quality glass in portable computers. The coated layers are; a nickel alloy layer, a chromium layer, a cobalt based alloy layer containing platinum, a carbon layer and a lubricant layer. The magnetic properties of the cobalt based alloy allow for "bits" of data to be stored in the disc, in circular tracks. The addition of platinum to the cobalt alloy enhances the magnetic qualities and enables data to be stored at higher densities. Another important electrical application for platinum is in the production of thermocouples for specific high temperature applications. The majority of platinum thermocouples manufactured are sold to the steel and semi-conductor industries. The recent decline in world steel and semiconductor production has seen a drop in platinum demand for this application.

Vermaak (1995) reports that the electrical industry also makes use of a small amount of platinum plated metals. The process of electroplating of platinum onto other metals is known as electro-deposition. Such a process improves the qualities of the final product, making it resistant to corrosion and chemical attack.

3.2.4 Glass manufacture

Glass manufacture is heavily reliant on the properties of platinum (particularly its resistance to high temperatures and corrosion). The principle demand for platinum in the glass industry, is currently in the manufacture of liquid crystal displays (LCD's). Johnson Matthey (1999) report that 90% of the of LCD glass is produced in the Far East (primarily in Japan). Taiwan and South Korea have recently (1998) built LCD manufacturing facilities. Although all glass manufacturing facilities require the use of platinum it is mostly used for equipment and tooling and can be easily recycled on a toll basis (Vermaak, 1995).

Glass melting furnaces make use of platinum for bubbler tubes, electrodes and occasionally a furnace lining. Skimmer blocks, which remove surface debris from glass prior to conditioning, are made of platinum coated refractory blocks. Platinum refining systems are used to condition high quality optical glass. Other platinum apparatus that make use of its high temperature tolerance during glass manufacture include flow control devises, stirrers and gobbing units (Johnson Matthey, 1997). Most platinum glass manufacturing apparatus is comprised of a refractory substrate and either a platinum or a platinum-alloy coating.

The glass industry also makes use of platinum to manufacture glass fibre. This manufacture involves the use of bushing baseplates which contain hundreds of precisely formed jets from which individual filaments of glass fibre can be drawn.

3.2.5 Petroleum production

Platinum is used as a reforming catalyst in the production of various petroleum products. Legislation requiring cleaner fuels, and the increase in the global car parc, are responsible for driving platinum demand in this industry. The demand for unleaded petrol resulted in substantial purchases of platinum by refineries in South America, the Middle East and Asia in 1997. Johnson Matthey (1999) report on a current use of platinum catalysts in the dearomitisation of diesel fuels. This process is triggered by legislation requiring reductions in the aromatic and sulphur content of diesels in California and Sweden.

3.2.6 Other uses

Platinum is consumed for a wide range of "other" applications. The most significant of these applications, currently, are non-catalytic automotive parts, protection for turbine engines, cancer drugs and pollution control. Platinum is required for the manufacture of oxygen sensors which are used in on-board diagnostic systems (OBD). These systems are designed to monitor the environmental emissions of a vehicle and warn the driver of exceeding limits. Legislation (effective from 2000) will require the use of a greater number of oxygen sensors, in petrol powered vehicles, in North America and Europe. Legislation requiring OBD's in diesel powered vehicles is expected to be effective from 2003. These controls are expected to further drive demand for platinum. Another non-catalytic automotive part currently being produced is the platinum-tipped spark plug. It is used to improve durability and was fitted to over 85% of vehicles produced in North America in 1998 (Johnson Matthey, 1999).
Johson Matthey (1998) report that there is an increased use of platinum in the aerospace industry. It is used primarily in this industry as a protective coating for turbine blades exposed to very high temperatures in jet engines. Use in jet engines is currently stimulated by a strong demand for air transport and resulting orders for new aircraft.

As environmental awareness grows, there is an increasing demand for the use of platinum in pollution control. Johnson Matthey (1998) report that there is a significant increase in the use of platinum-containing catalysts to clean up emissions from petrochemical plants and diesel powered generators.

Platinum is used in the medical sector, as a cancer drug. This application requires the use of platinum compounds, administered together with other drugs in combination chemotherapy. In addition to cancer treatment, Jonnson Matthey (1999) report on demand for platinum in certain components of biomedical devices such as cathers. These devices are used in cardiac surgery.

There are a host of other uses for platinum all of which contribute to the current demand. Most of these have a small individual effect on the demand for the metal, but accumulately they account for some 305 000 oz of platinum.

3.3 New Uses for Platinum

Johnson Matthey produce an annual publication detailing all current research and development in new uses. This publication provides details of more than fifty new applications for platinum and it's alloys, for 1997 alone. Applications vary from use in electrochemistry to medicine (dentistry and treatment of tumours). The author believes that there is more research and development being carried out on increasing the practical use of platinum than there is on limiting it. Perhaps the most significant new technology involving platinum (in terms of demand) is the fuel cell, described below.

3.3.1 Fuel cell technology

Fuel cells are the priciple power source for electric vehicles (EV's). These vehicles are being developed as an alternative to conventional petrol powered vehicles, by all leading auto-manufacturers. They offer the consumer higher fuel economy, greater engine efficiency and both quieter and smoother operation (Air Resources Board[2], 1999). In addition, fuel cells produce zero or near zero smog-forming and greenhouse emissions. Nurdin (1998) describes the fuel cell as offering "the benefits of battery powered vehicles while avoiding the range, weight and cost penalties associated with batteries".

The fuel cell converts chemical energy into electricity by combining O_2 with hydrogen gas (Air Resources Board[2], 1999). The hydrogen gas is derived from hydrogen bearing fuels, such as methanol, natural gas or gasoline, through the use of a fuel reformer. The fuel cell consists of two electrodes (a cathode and an anode) with an electrolyte sandwiched between them. O_2 is directed over the cathode and hydrogen over the anode, generating electricity.

Fuel cell technology is currently in an advanced stage of testing. Daimler Chrysler, Ford, Toyota and General Motors have all announced plans to have EV's commercially available by 2004. Transit buses are being used in "public demonstration programmes" in several North American cities. Nurdin (1998) reports that nine fuel cell busses were employed in various cities from November 1997 to November 1998. Most notably, the public transport systems of Chicago and Vancouver include six "hydrogen fueled zero emissions busses". Many prototype passenger vehicles have been, and are being tested and this trend is expected to increase.

The current cost of producing EV's is reported to be very high. Nurdin (1998) suggests that costs would have to be reduced by some 90% to bring EV's in line with conventional vehicles. However, Ford and General Motors have indicated that in mass production the cost of EV's would be comparable to those of conventional vehicles. In addition to EV's, fuel cells are likely to be used for other applications such as generators and

battery replacement. Johnson Matthey (1998) recognize the following potential fuel cell markets:

- Cars
- Busses
- A stationary power source
- A portable power source
- A residential power source

It is estimated that they have the capability of reducing electricity bills by as much as 20%.

Production-line fuel cells for EV's are likely to require significant volumes of platinum in their production. Nurdin (1998) estimates that each EV will require about 10 g of platinum. This is approximately double the requirement of a conventional vehicle. Due to legislative pressures, and the drive towards fuel efficiency and energy saving, it is likely that the implementation of fuel cell technology will accelerate over the next five years. The first "mass-market" for fuel cell vehicles is expected to be available from 2004 (Air Resources Board[2], 1999). Nurdin (1998) estimates the annual platinum demand for fuel cell vehicles will reach 100 000 oz by 2007, 300 000 oz by 2010 and 3 Moz by 2020. This would be nearly double the current annual platinum demand for autocatalysts.

3.4 Summary

Platinum has specific qualities that are not found in any other commodity. These properties result in it being irreplaceable in certain applications in industry. The following factors put platinum's position in industry in perspective:

- The estimation that one in every five goods contains or is produced using platinum.
- The fact that it is dubbed "the environmental metal" and has an irreplaceable function in the conversion of harmful emissions in autocatalysts.

- It is considered a "strategic metal" by the US Government due to its role in defense, medical and telecommunications industries.
- It is estimated that new uses for platinum are being discovered daily.
- New technologies such as fuel cells are reliant on greater volumes of platinum.
- Developments in the fuel industry are likely to dramatically increase demand for the metal.

A large proportion of industies are reliant on the properties of platinum, which thus play a significant role in driving demand for the metal.

4 THE EFFECT OF LEGISLATION

One of the principle applications for platinum (palladium and rhodium) is as a "loading" in autocatalysts. The design of these autocatalysts is continually improved by automanufacturers as they strive to meet emission control standards. Standards are detailed in legislation and imposed by countries who have a growing awareness of the effect of emissions on air quality. As discussed in chapter 3, there is currently no substitute for the use of PGM's in emission control. The volume of PGM used increases both as more countries impose legislation and as legislation becomes stricter. Johnson Matthey (1999) comment; "higher loadings of platinum group metals will play a vital role in ensuring that vehicles can meet new limits, and we therefore expect further significant growth in demand". This chapter reviews the effect of emissions on air quality, the state of global legislation and the resulting demand for platinum.

4.1 The World Vehicle Parc

Nurdin (1998) estimates that the global vehicle parc will exceed 700 million by the 21st century. He estimates that this will be comprised; 500 million light duty vehicles, 150 million commercial trucks and busses and 100 million motorcycles. While the vehicle parc appears to be slowing in industrialised countries (which account for some 70%), it is growing with increase in urbanisation and industrialisation elsewhere. Daimler-Chrysler have suggested that it will exceed 1.6 billion by 2030.

4 THE EFFECT OF LEGISLATION

One of the principle applications for platinum (palladium and rhodium) is as a "loading" in autocatalysts. The design of these autocatalysts is continually improved by automanufacturers as they strive to meet emission control standards. Standards are detailed in legislation and imposed by countries who have a growing awareness of the effect of emissions on air quality. As discussed in chapter 3, there is currently no substitute for the use of PGM's in emission control. The volume of PGM used increases both as more countries impose legislation and as legislation becomes stricter. Johnson Matthey (1999) comment; "higher loadings of platinum group metals will play a vital role in ensuring that vehicles can meet new limits, and we therefore expect further significant growth in demand". This chapter reviews the effect of emissions on air quality, the state of global legislation and the resulting demand for platinum.

4.1 The World Vehicle Parc

Nurdin (1998) estimates that the global vehicle parc will exceed 700 million by the 21st century. He estimates that this will be comprised; 500 million light duty vehicles, 150 million commercial trucks and busses and 100 million motorcycles. While the vehicle parc appears to be slowing in industrialised countries (which account for some 70%), it is growing with increase in urbanisation and industrialisation elsewhere. Daimler-Chrysler have suggested that it will exceed 1.6 billion by 2030.

4.2 Impact of Air Pollution on Health

The increase in the world vehicle parc causes an ever increasing number of problems associated with air pollution. Emissions from vehicles include hydrocarbons (HC), carbon monoxide (CO), nitrous oxides (NOx) and minute particles of soot called particulate matter (PM). The combination of HC and NOx produces ozone, or smog, in the atmosphere. "Elevated levels of ambient ozone, CO and PM are shown to increase both human morbidity and mortality" (Nurdin, 1998). In addition HC emissions include human carcinogens.

Nurdin (1998) suggests that PM alone is responsible for the death of 60 000 people in the United States annually. The World Health Organization estimates the annual death toll that can be linked to all pollutant emissions of road traffic to be 80 000 in Europe. These statistics account for the acute impact of air pollution on health. Long term exposure to these pollutants may have a greater effect on human life expectancy!

4.3 Emissions Legislation (Development of Vehicle Standards and Regulations)

Developed (or OECD) Countries lead global consideration for air quality. They have, accordingly, imposed the strictest legislation on emissions control. North America, Europe and Japan account for about 76% of the worlds global car parc, with approximately 88% of vehicles fitted with autocatalists. This paragraph reviews the state of legislative control within these countries and the "rest of the world".

4.3.1 North America

In 1946 a State agency was set up, to implement clean air legislation in the California south coast basin. In 1968 the first controls to improve the air quality of exhaust emissions were set up nationally in the United States of America (USA). These "early" controls were met by engine tuning modifications. In 1970 the Environmental Protection Agency was set up. They established standards for air quality to protect health, property and the environment. The 1970 Clean Air Act (CAA) enforced the use of catalytic converters for the first time. These converters were required for all vehicles produced from a model year,1975. They were initially platinum oxidation catalysts, which were used to oxidise CO and HC to water. In 1981 three-way catalysts (which included rhodium to reduce nitrogen oxides-NOx to nitrogen and oxygen) were introduced nationally in the USA. Between 1981 and 1991 the USA car parc increased by 16% and the average distance traveled by 41% (Nurdin, 1998). As a result of these increases, some 60% of the population was subjected to air that did not meet air quality standards. The 1990 Clean Air Act Amendment set out even more stringent emissions controls for implementation in the model year 1994, to rectify this. This legislation also placed demands on the durability of emission control, requiring a minimum life for the system of 100 000 miles or ten years. California adopted the worlds toughest controls, with the implementation of the 1990 Low Emission Vehicle (LEV) regulations. These regulations required automanufacturers to progressively introduce four new classes of vehicle (with increasingly stringent emissions standards) between 1994 and 2003. In addition, the regulations required 10% of the vehicle fleet to be zero emission vehicles (ZEV's) by 2003.

In December 1997 the Environmental Protection Act finalised regulations for the National Low Emission Vehicle Programme. This was a voluntary programme which, with agreement of automaufacturers, would allow for cleaner emissions than those required in the Clean Air Act. In addition,

the programme would allow for standards to be met three years earlier than under Federal law. Federal law required a "phase II" study to assess whether the 1990 Act should require further reductions in emissions. A 1998 report to Congress concluded that there was a continuing need for emissions reduction to meet air quality standards for both ozone and particulate matter. In late 1997 California proposed further tightening of its Low Emission Vehicle standards, the "LEV II". This legislation will require the following standards to be phased in by model year 2004 (Air Resources Board[1], 1999):

- More stringent NOx standards for LEV's and ULEV's
- The introduction of a new category of vehicle, the Super-Ultra-Low-Emission Vehicle SULEV
- Longer life requirements for autocatalyst systems, 120 000 miles
- Light trucks and sports utility vehicles will have to meet the same standards as passenger vehicles.
- Diesel standards for NOx and PM being the same as those for petrol powered vehicles.

The limits imposed for emissions control at state (California) and Federal level are illustrated in Table 4.1 below (after Nurdin, 1998). Although CO limits have remained at 3.4 g/m since 1983 the test conditions, post 1983 were made more stringent. Tier II and LEV II standards are expected to require further significant reductions of emissions.

Table 4.1 United States federal and low emissions vehicle standards, expressed in grams per kilometre (after Johnson Matthey, 1999)

STANDARD	CO	HC	NOx
FEDERAL	3.40	0.250	0.40
TLEV	3.40	0.125	0.40
LEV	3.40	0.075	0.20
ULEV	1.70	0.040	0.20

USA vehicles are estimated to contribute more than half of the worlds NOx inventory, 42% of the volatile organic compounds inventory, 25% of the PM inventory and 80% CO emissions.

4.3.2 Europe

Clean air legislation that required the use of autocatalysts was first implemented in Western Europe in the late 1980's. Austria and Switzerland were the first two countries to enforce legislation in 1987, followed by Norway and Sweden in 1989. Germany and the Netherlands offered tax incentives to encourage the fitting of catalysts, in the late 1980's. The first "pan-European" legislation forcing manufacturers to fit emission control catalysts only came into effect in 1993 (Nurdin, 1998). In 1994 the European Union imposed "Stage II" standards for all new models from 1996 and all new production from 1997. These standards required a reduction of 19% CO and 48% HC and NOx, on the Stage I requirements. In addition, Stage II required all diesel vehicles to make use of catalysts. Stage III standards, requiring a 30 to 40% reduction in emissions for petrol powered vehicels and a 50% reduction for diesel powered vehicles, will apply from the model year 2000. Table 4.2 below sumarises the increased demand of legislation on emissions control in Europe. Further reductions are expected for a Stage IV standard which will be implemented in 2005.

Table 4.2 European emissions limits for petrol driven passenger vehicles, expressed in grams per kilometre (after Johnson Matthey, 1999)

YEAR	CO	HC+NOx	HC	NOx
1992	2.72	0.97		
1996	2.20	0.50		
2000	2.30		0.20	0.15
2005	1.00		0.10	0.08

4.3.3 Japan

Clean air legislation was introduced by Japan in 1975. These controls required most vehicles to be fitted with palladium-rich autocatalysts. Legislation was tightened in 1978, requiring all "gasoline-powered" vehicles to be fitted with autocatalysts. At this time the Japanese emissions control legislation was believed to have been the strictest in the world. Table 4.3 below summarises the increased demand of legislation on emissions control in Japan. It is expected that Japan will introduce "stricter" controls in 2000 (Nurdin, 1998).

Table 4.3 Japanese emissions limits for petrol driven passenger vehicles, expressed in grams per kilometre (after Johnson Matthey, 1999)

YEAR	CO	HC	NOx
1991	2.10	0.25	0.25
2005	0.67	0.08	0.08

4.3.4 Rest of the world

Although the rest of the world only accounts for 24% of the total gobal car parc, controls are expected to result in 46% of these vehicles being fitted with autocatalysts by the year 2000. Estimated percentages for autocatalyst equipped vehicles are presented in Table 4.4. below (after Nurdin, 1998).

Table 4.4 A forecast of autocatalyst equipped vehicles in the global parc, by 2000 (after Nurdin, 1998)

REGION	TOTAL GLOBAL PARC	PROPORTION EQUIPPED WITH AUTOCATALYSTS
North America	30%	100%
Europe	37%	43%
Japan	9%	100%
Rest of the World	24%	11%
TOTAL	**100%**	**57%**

4.4 Effect of Emissions Control on Demand for Platinum

Demand for platinum in autocatalysts is driven primarily by legislation and to a far lesser degree by vehicle sales. Emissions legislation (as discussed above), increases demand through; 1) tighter standards in existing legislation, and 2) new emissions control laws in industrialising countries. Young (1998) recognizes that the following important relationships exist between vehicle emissions and PGM autocatalysts:

- Three-way catalysts, currently, have the following variations in PGM composition; Pt-Pd-Rh, Pt-Rh, Pd-Rh or Pd only.
- Increased Pd loadings are allowable (ito. emissions) only because of advances in fuel technology.
- Platinum is the most effective catalyst for NOx toxicity.
- Palladium is the most effective catalyst for HC, but is less durable with poor fuel quality.
- "Multi-catalyst" emissions control solutions are common.

Figure 4.1 clearly illustrates the impact of increasingly stricter emissions control on PGM demand. Demand for PGM in autocatalysts has doubled since 1993 and now exceeds 6 Moz. There has, however, been a significant change in the mix of PGM's consumed by autocatalyst producers. Palladium, currently accounts for more than half of total demand (Nurdin, 1998). This is drastically up from 1993 during which it

accounted for a quarter of PGM consumption. These facts are the result of the auto-industries "aggressive tactics" in seeking out cost savings for autocatalyst manufacture. Savings over the last few years have been achieved by switching from platinum-rhodium rich catalysts to palladium rich and trimetal catalysts. A perceived shortfall in palladium supply resulting from an estimated shortage in supply from Russian stockpiles is likely to cause consumers to revert back to platinum rich autocatalysts in 1999. In addition, specific requirements of legislation (which specify the reduction in NOx emission, for which palladium is not ideal) is likely to cause an increase in automanufacturer preference for platinum. The greater use of palladium in autocatalyst loadings has benefited producers with high pd:pt ratios in their ore reserves. Russian and Canadian Producers have derived particular benefit from the increased use of palladium, whilst producers with low pd:pt ratios such as those in the Bushveld and Stillwater Complexes have not. Hochrieter (1998) suggests a world pt:pd:rh ratio of supply, of 1:1:0.1. He suggests that automanufacturers should take cognisance of this ratio in terms of the loadings on convertors. Every change in the PGM composition of an autocatalyst involves significant time and cost.

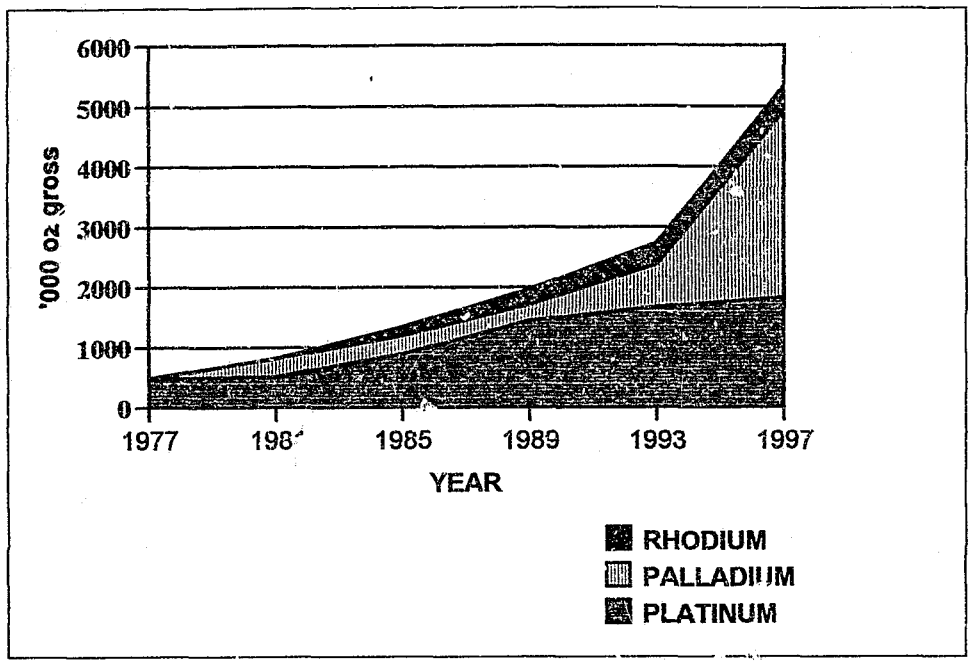


Figure 4.1 World PGM demand for autocatalysts (data sourced from Johnson Matthey, 1998)

The fuel source used by vehicles further complicates the choice of catalyst required by consumers to meet controls. Diesel engines produce less CO and HC's than petrol engines, but more NOx. Platinum is particularly suitable to dealing with NOx and is used in de-NOx diesel catalysts, which are being required by legislation.

Nurdin (1998) estimates that the average light passenger vehicle, currently produced, requires a PGM loading of approximately 3 g/t. If consumers choose other technology (currently being developed) to cope with legislative demands this is likely to increase. Fuel cell powered vehicles (NE cars, as described in chapter 3) are estimated to require 8 g/t PGM loading.

Finally, the durability of an autocatalyst is dependent on the choice of PGM loading. Platinum is the least sensitive to poisoning impurities (e.g.; lead and sulphur). Palladium, only, loading gives the autocatalyst improved performance at low temperatures and greater resistance to

deactivation at high temperatures. The addition of rhodium to a palladium catalyst increases the catalysts ability to deal with NOx.

While it generally agreed that increased emissions control enforces higher PGM loadings the above mentioned factors seriously complicate and limit auto-manufacturers choice of the specific "mix". Although palladium has been extensively used as a cheaper alternative to other PGM loadings, price and stricter emissions standards are likely to see consumers revert back to using a higher percentage of platinum. This reversion could be effective as early as 2000. Alternative technologies, capable of meeting strict emissions standards, are still being developed. It is likely that these technologies (particularly fuel cells) will actually make use of greater quantities of PGM than the autocatalyst.

As mentioned in chapter 3, legislative control on emissions also causes an increase in demand for platinum in emissions measurement. Platinum (because of it high temperature resistance) is used in oxygen sensors, which measure emissions levels in on-board diagnostic systems (OBD's). Legislation places increasingly stringent demands on the use of these systems to monitor emissions and warn the motorist of exceeding emissions limits.

4.5 Summary

Due to increasing environmental consciousness economically developed countries have enforced the use of catalytic converters through legislation. This legislation ensures a demand for platinum from automanufactures and gives confidence in the market to suppliers. North America, Europe and Japan, currently lead in the drive for stricter emissions. These emissions restrictions are imposed at specific "model years" and result in a required, ever increasing PGM loading. Although there is an increasing desire for manufacturers to save on loadings and substitute between the individual PGM's, the use of platinum in

automanufacturing is essential. New legislation requiring significant reductions in emissions is expected to be enforced from 2000. This fact, together with expected palladium price increases is expected to continue to drive demand for the use of platinum in vehicles over the next five years. Legislation is a unique and significant "driver of demand" for platinum. Changes in standards enforced by various Governments must be considered when accounting for world platinum consumption.

5 THE PLATINUM JEWELRY AND INVESTMENT MARKET

In addition to research and development (into platinum minting, and design and manufacture of platinum jewelry), innovative marketing by suppliers and producers has created a thriving market for platinum as a store of wealth and jewelry piece. Jewelry marketing has resulted in substantial increases in demand for the metal in Eastern markets. This chapter examines the success of marketing strategies and other reasons for the accelerated growth in demand in this application. Estimated current and future demand for platinum in jewelry and investment products is also presented.

5.1 Jewelry

The earliest record of platinum used for decorative purposes and religious worship, is of its use by pre-Columbian Indians in about 1500 BC*. The Egyptians made use of platinum in the famous Thebes casket in 700 BC* (Vermaak, 1995). Platinum was first used by the royal courts of Europe, for jewelry and decoration some 200 years ago (Taylor and Biggs, 1999). The earliest European example of platinum use was in a medallion made for Czarine Catherine of Russia in 1762 (Vermaak, 1995). Manufacturers such as Cartier, Tiffeny, Van Cleef and Arpels, and Faberge used the metal for their creations during the Art Deco period (1915 to the 1920's). It became the preferred precious metal for fine jewelry pieces in America for the first 40 years of the 20th century (Courage, 1999). Use of platinum was disrupted during the second World War, at which stage it was declared a "strategic metal" and scarce supply was diverted to the war effort (Taylor and Biggs, 1999). This event resulted in the development of white gold as a substitute for platinum in jewelry. Platinum only began to recover from this substitution through demand created in Eastern markets in the 1960's.

Although hallmarking standards vary from country to country, about 95% platinum by weight is most commonly used for jewelry and investment products (Taylor and Biggs, 1999). The remaining 5% is made up of a; copper, cobalt, ruthenium, palladium, iridium or gold alloy. Each different alloy imparts different properties to the item being manufactured. For example, the use of cobalt produces a superior casting alloy, and the use of gold a "warmer" colour alloy.

Platinum demand for jewelry, is currently the most important area of demand for the metal. It has recently, for the first time (in 1996) overtaken demand for use in autocatalysts. Cowley (1998) reports that world demand for platinum in jewelry grew by 68% from 1988 to 1998. Over the same period non-jewelry platinum demand has grown by only 38%. Since 1993, demand for platinum jewelry in China has increased 30 fold. Demand in jewelry, particularly in Eastern Markets is currently estimated to account for about 41% of total annual platinum demand. The demand is primarily driven by the good marketing practices of a group called Platinum Guild International (the marketing "arm" of Amplats). They have successfully exploited the bridal and investment markets in Eastern countries. Markets in China and Japan are founded on the "Eastern" preference for platinum as a choice of precious metal. These populations favour platinum over other precious metals and alloys (such as gold, silver and white gold) for the following reasons:

- **Purity:** Platinum jewelry, as opposed to gold jewelry is manufactured from a pure metal. Gold jewelry pieces usually contain between 58% (14 ct) and 75% (18 ct) gold metal. Eastern populations have a strong (cultural?) preference for purity, and thus pure metal in jewelry.
- **Fashion trend:** There is a strong, and growing "fashion trend" for "white metal" in Eastern Markets. Marketers suggest that this results from the contrast of the metal with the "Eastern skin".
- **Ideal set for diamonds:** Cut diamonds sales for engagement and bridal rings has strongly assisted platinum jewelry demand. Eastern populations prefer diamonds set in platinum than in other metals. In

addition, it is an extremely strong metal and ideally secures gems. This "link" benefits both De Beers and PGI as marketers of the two products. Cowley (1998) reports that recent promotions on cut diamond sales in China have stimulated demand for platinum rings.

- **Regulations on precious metal trade:** The regulation of the gold jewelry market in China has had a negative effect on gold and caused a preference for non-regulated platinum jewelry.
- **Greater profit margins:** Jewelry manufacturers are able to gain better profit margins on platinum than on other precious metals.
- **Qualities of platinum metal:** Platinum is hypoallergenic, resists tarnish and is one of the worlds strongest metals.
- **Rarity:** Platinum is one of least abundant elements, having a lithospheric abundance of only 0.005 ppm. Approximately ten tons of ore are required to produce one ounce of platinum.

5.1.1 Platinum Guild International

Platinum Guild International (PGI) is a specialized marketing organization that was set up by the Rustenburg Platinum Mines in 1975 (Courage, 1998). The organization is supported by other producers; Lonplats and Implats, and most jewelry fabricators. It initially concentrated marketing activities in Japan, Germany and the United Kingdom. In the 1980's PGI initiated a coin and investment programme. It extended its jewelry programme into Italy in 1987, the USA in 1992 and China in 1997.

The principle objective of PGI is to "develop effective marketing programmes to stimulate demand for jewelry and coins" (Courage, 1998). In order to achieve this objective they have had to overcome the following traditional problems:

- Platinum has always been one of the most difficult precious metals to "work" (due to its hardness and high melting point).
- Retailers have been hesitant to stock platinum jewelry because of the relatively small demand.

- It is very similar in appearance to silver, white gold and even stainless steel. Such metals and alloys have acted as a far cheaper substitute.
- Would-be consumers have struggled to find jewelry outlets which stock platinum pieces.

In addition, PGI have had to change a market for platinum jewelry which focused on the older and wealthier age group, and comprised expensive and highly decorative jewelry pieces. They have developed a changed, affordable market comprising simple, modern and wearable pieces aimed at the younger age group. Above all they have used emotional occasions to increase platinum jewelry sales. Courage (1998) lists a shift in consumer attitudes and an increase in the available range of metal only, and gem set platinum jewelry, as key developments in the platinum jewelry market.

The main activities of PGI (as listed by Courage, 1998) include:

- Targeted television and print advertising.
- Trade partnered advertising.
- Point of sale materials
- Effective public relations and publicity programmes.
- Training of technical and retail sales persons
- Research

PGI has achieved significant growth in demand for platinum through marketing programmes (strategies) designed to cater for specific markets, populations and cultures. Table 5.1 illustrates some of the strategies that PGI have adopted by region in which it operates. They have indicated that they will continue to drive demand in these regions, particularly in China and the USA, which have not yet reached full potential. New programmes will be launched in India and Taiwan, in 2000 (Courage, 1999). The former being the worlds largest gold market (and fifth largest diamond market) and the latter being a very similar market to China.

Table 5.1 Strategies and results of PGI marketing prior to 1999 (data is sourced from Courage, 1998/9 and Cowley, 1998)

COUNTRY/ REGION	STRATEGIES	RESULTS
JAPAN	• Introduction of a betrothal ring (the Posy) and lower priced platinum metal jewelry aimed at the younger age group. • Jewelry counters placed strategically on the ground floor of department stalls . Sales to benefit from store traffic and broader consumer base. • Platinum marketed as "every day jewelry". Manufacturers persuaded to produce new lighter weight designs for earrings, necklaces etc. • Advertising makes use of a well known and admired personality during key purchasing periods.	Decrease in demand for Engagement wedding and fashion rings due to poor economy (1997 to 1998). Good growth, however in demand for necklaces, earrings and bracelets. In addition share of jewelry market grew.
CHINA	• Build on established sales in a few major urban centers, first. • Focus on metal only jewelry. • Aim at target market (woman aged 20-40, urban dwellers, mid to high income level, better educated, receptive to trend and fashion, aspire to better quality of life) • Inform manufacturers, retailers and consumers. • Look at owning an occasion. Launch the posy concept (pieces under $120) . Its purchase should become the preferred way to express love.	Continued high growth in consumer demand.
EUROPE	Germany: • Separate market focussing on design and selling through studios. Italy: • Developed as manufacturing market for export jewelry • Development of bridal and "young" markets • Launching of platinum export catalogues	Growth from 150 000 oz in 1997 to 160 000 oz in 1998.
USA	• Development of a platinum bridal programme with the assistance of gold jewelry manufacturers • Promotion campaign launched, aimed at informing the trade and then the consumer. • High impact trade show presence • Issue retailer outlets with a platinum "starter kit" • Break into USA's largest Jewelry chain (Zales). • Launch consumer friendly platinum jewelry website. • Maximise use of publicity (magazines, TV, competitions etc.)	Growth in demand from around 20 000 oz in 1991 to 200 000oz in 1998.

5.1.2 Jewelry products

Platinum jewelry products can be classified as; non bridal rings, bridal rings and accessories (necklaces, bracelets, earrings and pendants). Bridal (engagement and wedding) rings are the most popular products. They account for the largest sales of world platinum jewelry. Cowley (1998) discusses the difference in current consumer demand for various gold and platinum jewelry products in the USA. It is interesting to note these consumers of platinum have a 95% preference for bridal rings over other products. Sales of rings (bridal and non bridal) dropped in Japan from 6[illegible]% of their jewelry market in 1994 to 56% in 1999 (Courage, 1999). This was compensated for by sales in accessory products which went up, during the same period from 32% to 44%. Chinese jewelry consumers have a preference for platinum chains over rings and other accessories. Chains, in this country, account for 46% of current consumer preference and rings, 44% (Cowley, 1998).

5.1.3 Growth in jewelry demand

Share of the market

Consumer preference for platinum jewelry over other precious metal jewelry, has affected the "market share" for precious metals in Eastern countries. Courage (1999) reports that platinum jewelry is replacing demand for gold jewelry in Japan. He shows that the gold share of the Japanese jewelry market has dropped from 72% in 1994 to 62% in 1999, at the expense of consumer preference for platinum. The result is that the platinum jewelry share has increased from 21% to 34% for the same period. This is illustrated in figure 5.1 below.

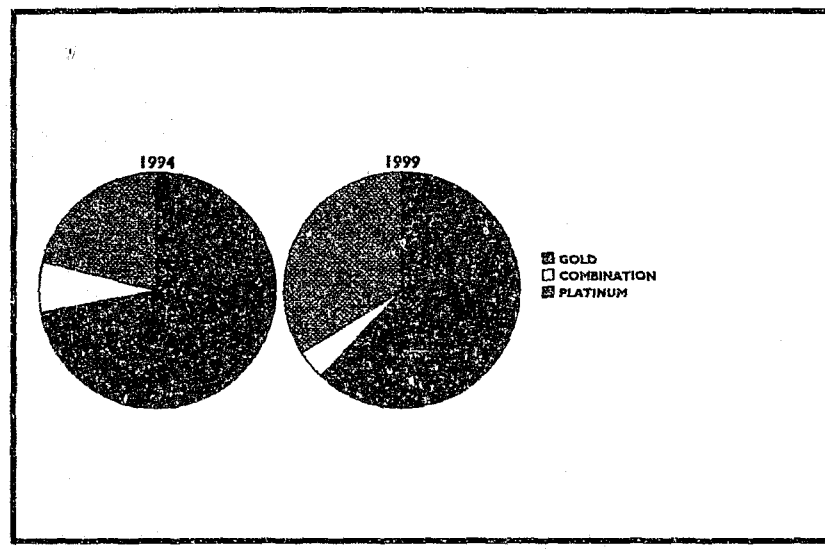


Figure 5.1 The variation in the platinum and gold share of the Japanese jewelry market from 1994 to 1999 (data is sourced from Courage, 1999)

Jewelry demand by region

As mentioned above, their is a strong preference for platinum metal in jewelry, in Eastern markets. Western markets for jewelry are far smaller and generally based on specific, limited pieces. The following is a brief overview of current platinum consumption in the largest jewelry demanding countries and regions.

Japan leads current world platinum jewelry consumption with a 50% demand (Courage 1999). It currently consumes about 1.3 Moz platinum for use in jewelry. Demand in this sector increased from 1.35 Moz in 1993 to a high of 1.48 Moz in 1996 (Johnson Matthey, 1999). It has since dropped to 1.3 Moz and is the only major region showing negative growth. Japan's dominance of the world platinum jewelry market has dropped from 78% in 1993 to 50% in 1998 (Courage, 1999). Johnson Matthey (1999) attribute this drop to an economic downturn and a "sharp fall in consumer spending on luxury goods".

China is the second largest consumer of platinum for use in jewelry with a 26% share of the world market, some 620 000 oz (Johnson Matthey, 1999). As mentioned above, platinum jewelry demand in China has increased thirty fold from 1993 to 1998 (Cowley, 1998). Courage (1999) reports that China's share of world platinum demand has increased from 1% in 1993 to 23% in 1998. Johnson Matthey (1999) attribute this growth to successful advertising and promotional campaigns "stimulating a surge in sales to young consumers".

North America currently accounts for 9% of world platinum jewelry demand (Johnson Matthey, 1999). An increase of 60 000 oz in demand from 1997 to 1998 is reported. This is attributed to increased sales of rings and the expansion of retailers ranges, to include necklaces and earrings, in the USA (Johnson Matthey, 1999).

Europe currently accounts for 6.5% of world platinum jewelry demand (Johnson Matthey, 1999). A small increase of 5 000 oz was experienced in demand in this region. Johnson Matthey (1999) attribute this increase to an increase in lightweight chain fabrication in Italy and an increase in consumption by the bridal sector of the UK market.

The rest of the world, currently, only accounts for some 3.5% or 85 000 oz of platinum jewelry demand (Johnson Matthey, 1999). The majority of this demand is from other Asian countries (predominantly Taiwan and India).

Current growth in world jewelry demand is shown in Figure 5.2 below. The rapid growth in Chinese consumption and the recent decline in Japanese consumption, for 1998 is clearly illustrated.

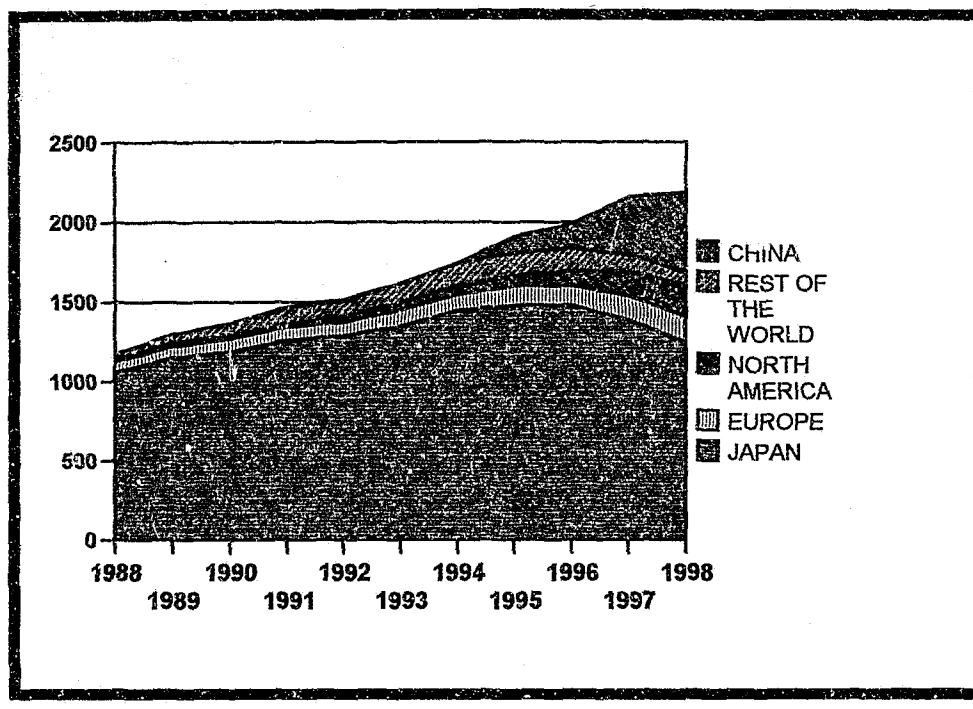


Figure 5.2 World demand for platinum in jewelry (data is sourced from Johnson Matthey, 1998)

Future jewelry demand

World platinum jewelry demand is expected to continue its current growth on the back of increased marketing initiatives by PGI. Courage (1999) forecasts that PGI marketing will continue to drive consumer demand for platinum jewelry in China, the USA, Italy and Germany. Overall demand for jewelry and specific demand for accessories is expected to increase substantially in 1999 in Japan, with an upturn in the Japanese economy. New markets are being established by PGI in other European and Asian countries, with India and Taiwan showing potential for rapid growth in demand in 2000. Overall platinum jewelry demand is forecast by Courage (1999) to increase from its current levels of 2.27 Moz to 3 Moz in 2000 and 4 Moz in 2004. PGI plan to achieve this forecasted growth by increased intensity of marketing in their five main markets (Japan, China, Italy, Germany and USA) and by "setting platinum apart as the ultimate precious metal" (Courage, 1999).

5.1.4 Creation of a platinum inventory

Increased annual sales of platinum jewelry pieces, has resulted in a large build up (or inventory) of platinum metal that is not "truly consumed". As annual world demand increases, so the holdings of jewelry pieces increase. The net result is a platinum jewelry inventory that, at the right price, would augment world supply. Courage (1999), however states that platinum when used in jewelry "does not come back to the market" and rather, "provides a steady offtake". Although this may hold true at current prices the author believes that at higher prices, platinum (from jewelry holders) *would* come back to the market and be made available for specific and irreplaceable applications.

5.2 Investment

The investment sector for platinum demand is made up of small investment products (which include coins and small bars) and large investment products (or large bars). Small bars refers to all platinum bars less than 500g and large bars are bars exceeding 500g. Coins are manufactured (or struck) by mints. Bars are produced by fabricators such as Tanaka Kikinzouku Kogyo (TKK), Engelhard Corporation, Johnson Matthey and Co. Ltd. and Degussa.

5.2.1 Large bars

Large bars are traded as investment products in Japan and are characteristically purchased in the form of half or one kilogram bars. This market is price sensitive. A sharp drop in platinum's yen value is typically accompanied by a strong increase in demand for large bars. Conversely an increase in price will encourage investors to sell metal back to the market (Johnson Matthey, 1999).

5.2.2 Small investment products

Small investment products include platinum coins and small bars. These products constitute a 210 000 oz world demand for platinum, with North America currently accounting for 175 000 oz of consumption of the metal in this form Johnson Matthey (1999). Japan is currently the second largest consumer with 25 000 oz. The rest of the world is estimated to consume about 10 000 oz.

Small bars were first produced by Tanaka Kikinzouku Kogyo (TKK, the leading bullion house in Japan), following the collapse of the Betton-Woods agreement and the oil embargo of 1975. They produced five and ten gram bars that were "small enough for the individual investor to buy" (www.researchmag.com, 1997). In 1982 the two largest European fabricators, Engelhard Corporation and Johnson Matthey and Co. Ltd. (JM) began producing one and ten ounce platinum bars. Since 1982 a variety of small bars have been produced by JM, Engelhard, TKK and Degussa.

Platinum coins are by far the most popular and secure way to hold platinum and are not subject to assay, as their weight and purity are backed by the issuing nation. In addition, they are portable, "liquid" and often quite attractive. Coins are usually minted as bullion coins and proof coins. Bullion coins are consumed as an investment into the metal they are comprised. Proof coins (also known as numismatic or collectors coins) are valued and collected for their inherent beauty and intrinsic value as a work of art. They are more expensive than bullion coins and are sold in limited additions. A considerable amount of specialist labour is required in the production of proof coins. The first platinum coin minted was the Noble, which was minted by the Isle of Man in 1983. Cook (1998) lists the Platinum Eagle, Australian Koala and Canadian Maple as the most successful small investment products. American Eagle, proof coins and sets were first sold in June 1997. By November 1998 they had already

accounted for 89 000 oz of platinum. Johnson Matthey (1999) report that "the Eagle has taken the market share from other coins". They estimate demand for American Eagles to total 175 000 oz for 1998, which is well in excess of 90% of the coin market. Demand for American Eagles is concentrated in the USA, but is growing in Japan where it is centered around smaller coins weighing one tenth or one quarter of an ounce (Johnson Matthey, 1999). These coins are often incorporated in jewelry items. Cook (1998) describes the appearance of platinum coins as "cold" and suggests that the American technology applied in "warming up" the metal used, is largely responsible for its attraction. He suggests that proof coins are struck as many as nine times to achieve the desired quality.

In addition to the Eagle, Koala and Maple there are dozens of other platinum proof coins which have been released to satisfy numismatic demand. All these coins derive their value from both the platinum they contain and the collector demand for various issues. China's Panda coin is a good example of a platinum proof coin that is popular with collectors. China have released this coin in a number of different weights to increase demand. Russia is also active in the platinum coin trade having issued an estimated 18 different platinum legal tender coin designs between 1987 and 1997 (www.researchmag.com, 1997). Their most recent issue is the Ballerina proof coin. Besides its bullion coin, the Isle of Man is estimated to have minted some 26 unique platinum proof coins between 1979 and 1997.

Currently, a platinum investor can choose between legal tender coins, bullion bars or numismatic coin products. Tanaka Kikinzoku Kogyo (TKK) play a large role in Japanese consumption of platinum investment products, with the opportunities that they offer investors. Their most successful option is a monthly accumulation plan which was launched with gold in the 1980's and is now offered for platinum. This Platinum Accumulation Plan (PAP) allows the investor the opportunity of investing a

monthly amount in platinum metal (Winter, 1998). The investor can then withdraw the investment of platinum in the form of coins, bars or jewelry.

South Africa's lack of ability to beneficiate a proportion of its vast platinum production is most evident in the Coin Market. Although it has a modern Mint facility situated near the capital in Gauteng, it is currently only able to cope with "softer" precious metals. It currently produces a variety of gold bullion and proof coins, which are consumed both by domestic and export countries. The Kruger rand is the most well known of these. Cook (1998) sites the following reasons as inhibiting to the production of South African platinum coins:

1. South Africa (SA) does not posses facilities for the manufacture of platinum blanks. Such blanks would have to imported from the Perth Mint Gold Corporation in Australia.
2. Authority must be attained from the SA Reserve Bank, Minister of Finance and Parliament prior to the launch of a legal tender platinum proof and bullion series.
3. The Minister of Trade and Industry must provide exemption from tax on sales of coins and import duties on blanks.

It is reported that the SA mint is in the process of "drawing experience from the Americans, Canadians and the Gold Corporation before launching our own programme" (Cook, 1998).

The author believes that the problems faced by the SA mint are relatively insignificant and that this is a seriously neglected area of potential beneficiation for platinum. It would be an ideal use for platinum produced in excess of ounces required to meet supply contracts. The reason for not beneficiating platinum any further than refining, may actually have more to do with the producers reluctance to "upset" consumers (Fenner *pers comm*). The perception that exists is that production of coins by the SA mint may cause a share of the market to be removed from other coin mints. As the platinum used in the minting of the American Eagle (which controls 90% of the market), is derived from Stillwater, the author does not

believe that it *would*, however, be affected by minting of SA produced platinum.

5.2.3 Future demand for investment products

A potential shortfall in platinum supply for 1999, is expected to drive up prices. High platinum prices have traditionally driven away investors and significantly reduced demand for platinum investment products. Demand for platinum investment products in Japan is extremely sensitive to the yen platinum price (Johnson Matthey, 1999). This is illustrated by the surge in purchases of large bars following a plunge in the platinum price in the last quarter of 1998. The predicted drop in demand for platinum investment products is likely to be partially offset by the purchase of coins for use in jewelry and the Japanese accumulation plan, mentioned above.

5.3 Summary

PGI have established a remarkably successful jewelry and coin market for platinum over the last ten years. They have been particularly successful in an Eastern betrothal market. This market undergone two key changes to platinum supply and demand, viz:

1. Demand for platinum in Jewelry has over taken demand for platinum in autocatalyst production.
2. A key producer now plays a large role in controlling consumption of platinum for the first time.

The author believes that this relatively new market for platinum demand will have a significant impact on the traditional situation of "consumers being price makers and producers being price takers".

The launch of successful bullion and proof coin issues, such as the American Eagle has further enhanced demand for platinum. Although coins are seen more as investment products and jewelry is seen more as an object of attraction, both products have similar markets. In addition, the

rapid growth in demand for both products serves to increase inventories of platinum metal that is "not truly consumed". Investment products are especially price sensitive. Such platinum is likely to be returned to the market at high prices.

6 RUSSIAN PLATINUM SUPPLY

Russia is a net world supplier of platinum, producing more than it requires for its domestic usage, and accounting for some 20% of world supply. The accuracy of the world supply and demand balance is dependent on the accuracy with which Russian supply can be estimated. Analysts such as Hochrieter (1998) suggest that understanding Russian Supply is "the single most important factor in platinum price prediction".

Annual Russian supply of platinum onto world markets has been exceptionally variable (as illustrated in figure 6.1, below) and difficult to predict. The difficulty stems from a lack of accurate information available, and confusion in the following areas:

- Russian resources (grades, manipulation and exploitation)
- Annual production
- Double accounting of "Russian looking metal"
- The creation and depletion of Government controlled stockpiles
- Government strategies

The lack of reliable information is a result of the fact that all precious metal supply statistics are considered to be State secrets in Russia. Christian (1998) remarks that "even when a government official makes a public statement, one has to question the rationale for the public comment and the accuracy of information being purveyed". This chapter discusses the areas of confusion and attempts to provide an understanding of the current state of Russian supply.

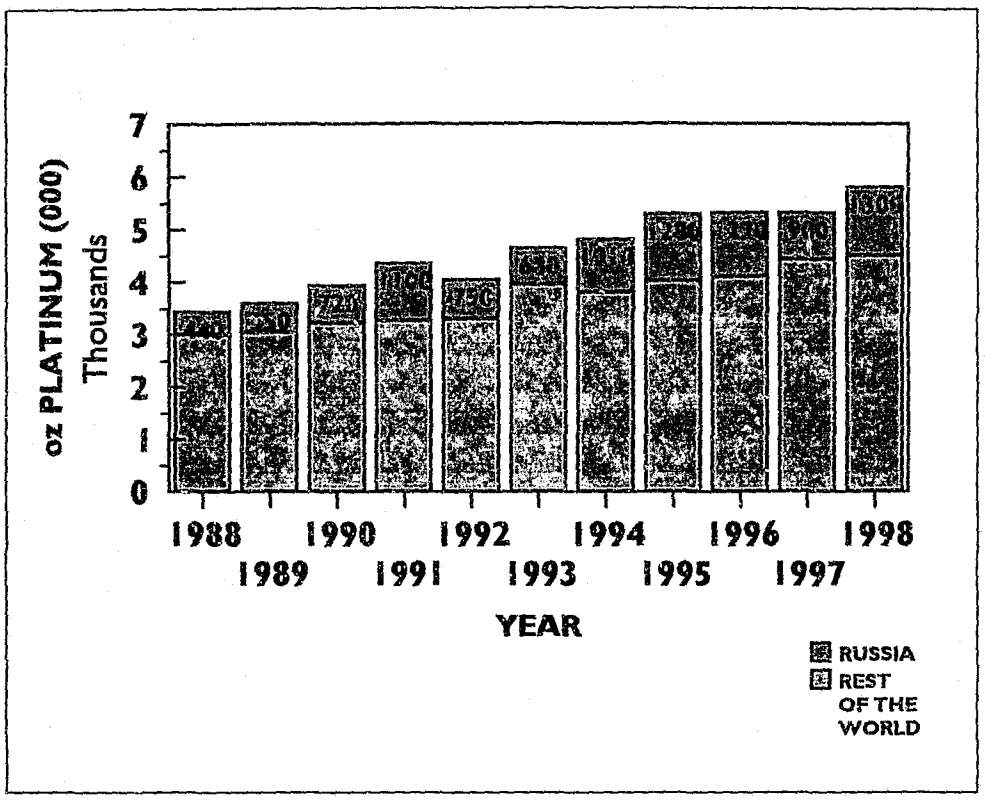


Figure 6.1 Variability of Russian supply (data sourced from Johnson Matthey, 1999)

6.1 Russian Resources

The Norilsk and Talnakh deposits currently account for the vast majority of Russian platinum production. A description of these deposits is given in chapter nine. The deposits comprise both massive and disseminated sulphide. Vermaak (1995) recognizes two distinct ore bodies of massive sulphide which he classifies as; copper-rich ore and pyrrhotite-chalcopyrite ore. He estimates that reserves comprise 60 km^2 disseminated ore and 19 km^2 massive ore. Various authors have provided "rough" estimations of grades (in the absence of reported information from Norilsk). Vermaak (1995) has summarized this information and suggests that a platinum grade of 2.19 g/t for massive ore and 1.65 g/t for disseminated ore is acceptable.

The Norilsk and Talnakh ores were targeted in the 1970's as ore for nickel exploitation. Existing mines are thus based primarily on nickel production and are dependent on the state of the world nickel market and the domestic nickel requirements of the country. Copper, job provision, palladium and platinum (in this order) are of secondary importance and considered to be by-products.

Most of Norilsk's existing shaft infrastructure is centered around the high grade massive sulphide "targets". As these "targets" become exploited, production is forced to concentrate more on the lower grade disseminated ores. Unless there is a major capital injection in the near future there will be little possibility of exploiting new reserves. This will cause the nickel grade of annual tonnage to drop from around 1.5% to around 0.31% (Vermaak's 1995 estimated disseminated nickel grade). If these deposits are still viable, mining of disseminated ore would also cause platinum grades to drop from 2.19 g/t to around 1.65 g/t. This would have a significant effect on annual Russian platinum production.

6.2 Annual Production

There are many factors affecting current and future production in Russia. Primary among these are the depletion of the ore bodies, the harsh physical conditions experienced by mining operations, high costs and the urgent need for capital injection. It is likely that the combination of these factors will reduce future production.

Although the Norilsk Nickel operations are widely spread across Russia, the company's largest area of production is the remote Taimyr Region. Other less significant platinum mining and refining operations of the Pechenganickel and Severonickel subsidiaries are concentrated in the Kola Peninsula of north-western Russia. Both of these regions (Taimyr and Kola) are situated in the Arctic Circle and are extremely remote. The Taimyr region is 3500 km from Moscow and 2000 km north of the nearest

major city Krasnoyarsk. Climatic conditions to which the operations and workers are exposed are extreme (see table 6.1 below)

Table 6.1 Severity of conditions at Norilsk

CONDITION	MAGNITUDE
AVERAGE TEMPERATURE	-9°
TEMPERATURE MINIMUM	-50°
MAXIMUM WIND SPEED	40 m/s (144 km/hr)
NUMBER OF POLAR DAYS	67 (lasting 24 hours each)
SNOW ON THE GROUND	244 days per year
AVERAGE MALE LIFE EXPECTANCY	45 years

Norilsk Nickel is not only responsible for the cost of mining and processing, but also incurs secondary costs of power supply and generation, telecommunications and transportation. Due to the climatic conditions and remoteness, these costs are excessive when compared with the costs of other mining operations in western world countries.

The cost of production is further augmented by the cost of infrastructure for the 300 000 people that the Norilsk operations support. The region of inhabitance around the operations is known as the Norilsk Industrial Region (NIR) and includes Norilsk, Talnakh, Kayerkan and Dudinka (Norilsk Nickel, 1999). The Norilsk mining and metallurgical operations, known as the Combine, are responsible for all of the infrastructural costs required by these populations. These costs include the generation and supply of power, the supply of water and food, education, medical facilities, roads and transport etc.

It is very clear to most commentators that Norilsk has a significant shortage of capital, which is urgently needed to fund:

- Metallurgical upgrades needed to cope with increased production from disseminated ores.
- Social infrastructure costs (which, as explained, are particularly high).
- The urgent replacement of outdated and expired equipment.
- Expansion of mining infrastructure into higher grade reserves.

Russian producers have, under a socialist regime, never had the need to consider cost of production of their metals. Until very recently all costs were absorbed by the State. As a consequence, very little economic planning has traditionally gone into the cost of producing metals, and generating revenue. Most analysts believe that Norilsk is an excessively expensive operation and that the potential for profit is marginal. In addition, the operations are dependent on a favourable nickel market (platinum being produced only as a by-product). Although the country has moved towards a democracy, there is still a strong adherence to socialist practices, and a primary function of Norilsk and the Taymyr region is to provide much needed employment. Reports suggest that salaries payable are well in arrears and equipment that is vital to the operations is either expired or in need of repair (Hochrieter, 1998). Given the above facts, very few Western world investors would look towards Norilsk operations as a potential investment. The controlling company and the State (who control the sale of all precious metals), are bankrupt or close to bankrupt, and thus have no means of supplying the urgently needed capital. Although the potential for high grade deposits exists (and Norilsk has the ability to manipulate the mining of these deposits to suit market conditions) the lack of capital is a significant barrier to any such expansions and threatens the existing annual production. The author believes that without an urgent capital injection, there will be a steady decline in annual production from Norilsk and its subsidiaries over the next few years.

6.3 Double Accounting

Two factors have traditionally contributed to double accounting and over-estimation of Russian platinum output in the past:

1. The double (or triple) counting of "old" platinum shipments, as bars held by investors, fabricators and dealers moved around the world. These platinum shipments are believed to have originated in Russia in the 1970's and 1980's. Christian[2] (1998) suggests that this Russian metal may have been counted three times as it moved from the USA to Switzerland and finaliy, to Japan.
2. The effect of counting "Russian looking" metal that is toll refined in Russia, but is not Russian mine output. This metal is derived from small scale Western producers and expired autocatalysts that have been reclaimed in Europe.

6.4 Stockpiles (Government Controlled Exports)

All Russian precious metal production is "regulated by Presidential Decree" (Norilsk Nickel, 1999). In accordance with this decree, all platinum produced by Norilsk Nickel (for Uneximbank) must be conceded to the Government. In addition, Uneximbank does not own a license allowing it even to deal in platinum. Once the annual production has been received by the Government, the Ministry of Finance decides how much platinum will be 1) stored, 2) made available to domestic fabricators and 3) exported (Christian[2], 1998). The stored metal is placed in "strategic stockpiles" which are managed by a division of the Army. All export is managed by an authorised State body called Almaziuverlirexport (Almaz). This agency imposes quotas based on the volume of platinum the Government has chosen to make available for export. Quotas are imposed annually and place a limit on supply. Figure 6.2, below, is a comparison between Russian and Western supply. It illustrates the complicated route that Russian platinum "travels" from producer to

consumer. The Russian process, of making platinum available for export, is a complete contrast with a "free market system" as adopted by all other producers.

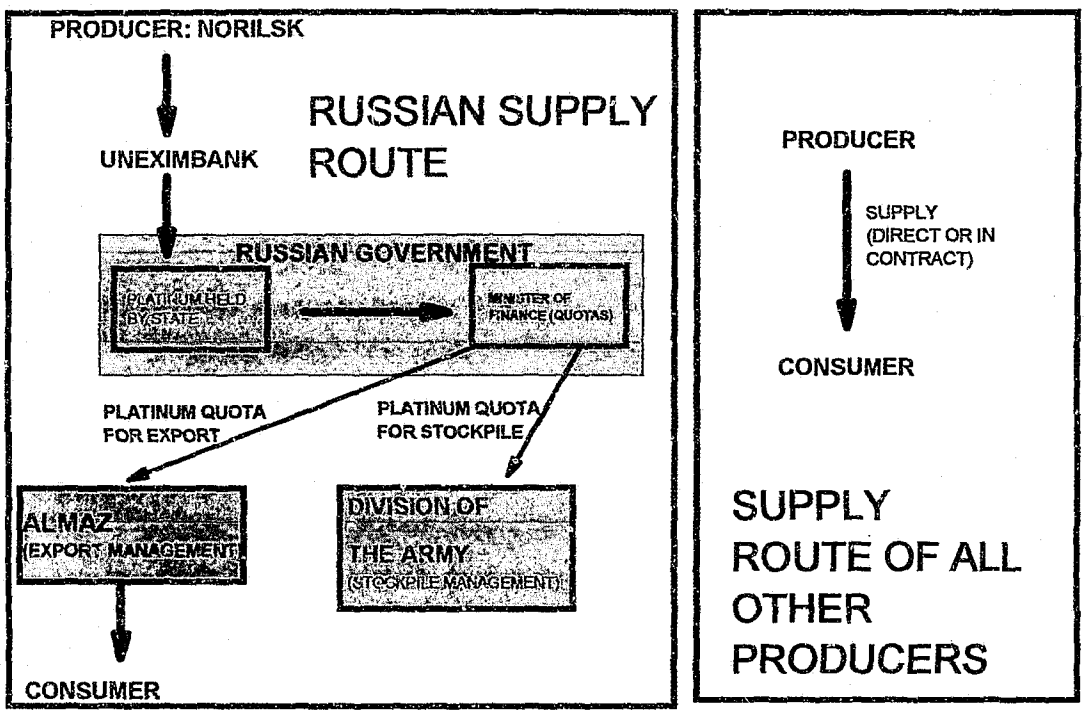


Figure 6.2 A comparison of the production-supply routes followed by Russia and other producing countries

6.5 Government Strategies

As mentioned above annual supply of platinum is controlled by the Russian Government via its Ministry of Finance. Annually, a decision is made as to whether platinum stockpiles will be augmented or depleted. This decision is the end result of Government strategies.

During the 1980's the Russian Government was strongly opposed to selling "strategic metals" to international markets at low prices. It took the view that inventories may be needed at some future time (Christian[2],

1998). Platinum exports for this period ranged between 200 000 oz and 500 000 oz per annum. As Russian economic conditions worsened in the 1990's, platinum exports increased markedly to around 1.1 Moz in 1991 and 1.2 Moz in 1995 and 1996. At this point the Ministry of Finance became concerned about 1) the depressed platinum prices received for "their" metal, and 2) the massive draw-down in stockpiles (Christian[2], 1998). The result of this was that the Ministry put a hold on all exports by Almaz, as it reviewed the situation. Over the last two years, this scenario has repeated itself, and has reinforced the erratic nature of platinum export quantities. In 1998 Norilsk attempted to offset losses incurred from a weak nickel market by producing additional PGM's. Due to the Governments decision to withhold supply, however, it was unable to derive the required revenue (Norilsk Nickel, 1999). The collapse of first quarter exports in 1997 and 1998 has provided an opportunity for other Western suppliers. The Norilsk Press Service estimates that this practice has cost Russia approximately $200 million to date (Norilsk Nickel, 1999). Consumers have a strong preference for steady supply and are thus, hesitant to enter into contracts with Russia.

Historically, Russian authorities have released platinum from stockpiles according to their own agenda, rather than in proportion to production. The persistant draw-down of stockpiles in the 1990's has resulted in the strong possibility that there is little remaining platinum that would currently be surplus to production. The manner with which the metal has been off-loaded or withheld from stockpiles (Russia's "sales policies") has therefore had a key impact on the platinum price in recent times (Hochrieter, 1998).

6.6 Summary

Russian influence on both world platinum supply, and the volatility of platinum prices, is most significantly influenced by the following factors:

- The erratic fluctuation of Russian stockpiles

- The potential for steadily decreasing mine production and exploitation of reserves
- The lack of disclosure of information regarding all aspects of annual Russian production and supply

Current knowledge of the role that each of these factors plays is vital to accurate predictions of the state of the world platinum market. It is accepted that Russian platinum supply currently faces the following problems:

- There is likely to be a substantial drop in mine production over the next few years, resulting from; the move from massive ores to disseminated ores as reserves of the latter run out in Norilsk, the lack of remaining alluvial reserves and the predicted decline of the nickel market.
- There is a lack of capital funding available to exploit new reserves, expand output capacity, deal with social problems and replace expired operational equipment.
- There are no, or virtually no remaining stockpiles.
- Russia refuses to disclose any accurate data regarding annual platinum supply. This will cause consumers who require a steady, reliable supply of platinum (particularly autocatalyst manufacturers) seek alternative sources.

The unpredictable off-loading of platinum onto world markets, together with the predicted drop in supply of approximately 400 000 oz per annum over the next five years has a significant effect on the balance of world supply and demand.

FOOTNOTE:* **Stockpile (Inventories):** As previously mentioned platinum is a virtually irreplaceable commodity in a number of products and consumers and governments often protect themselves against disruptions in future supplies by setting up stockpiles. Disruptions in supply are most commonly caused by; technical problems, war or unrest and industrial strikes. On the supply side, mining companies often hold back metal during periods of "soft demand". Stockpiles fall into two categories i.e.:

- LONG TERM STOCKS. These are mainly Government funded inventories (assumed to exist in Japan, Germany and the UK, and known to exist in the USA).
- SHORT TERM STOCKS. These include producer stocks (most impressively Russian and South African), importers stocks, refiners stocks, dealers stocks and consuming industries stocks.

Information as to volumes held in stocks is extremely scarce due to the strategic nature of the stockpiling exercise.

7 FACTORS AFFECTING PLATINUM PRODUCTION

Platinum supply is largely dependent on consistency and persistency of production from the worlds major platinum operations. Without supply consumers are forced to seek substitute commodities and thrift on the use of platinum. Producers strive for a steady increase in production but are constrained by a number of factors. This chapter reviews the following critical factors, viz.; cost, legislation, political stability, the status of the commodity and, availability of labour, reserves and technology. Certain specific constrictive steps hamper the steady production of platinum. They are called "bottle-necks" and are key areas at which production loss can be observed. This is discussed towards the end of the chapter.

7.1 Cost

The cost of producing of an ounce of platinum is the most significant factor affecting the competitiveness of a producer. Lowest cost producers are the most likely to survive price depressions. A high cost producer will be forced to curtail operations during periods of price depression. The cost of re-entry into the market and the start-up cost of production is usually a significant barrier to the commencement of operations once they have been curtailed. A cost curve for major primary product platinum producers is provided in figure 7.1. This graph shows the platinum producing companies that are most vulnerable in terms of price fluctuations. Vulnerability is offset by; Long term contracts and the ability of the company to revert to cheaper mining (usually of shallower reserves).

Costs of platinum production are incurred in mining and processing. These areas of production are discussed below.

7.1.1 Mining

Operational costs of mining (or ore extraction) are dependent on the type of ore body being mined and the method of mining employed. They include; cost of equipment, material, labour, power, water and environmental management. Producers must calculate the expected operational costs prior to mining in order to assess the viability of extraction. In addition, these costs should be continuously assessed by the producer during the life of the operation in order to best maximise returns.

Every platinum bearing ore body, world wide is unique in character. As a result the extraction of each different ore-type incurs specific costs. An example of such cost variation can be seen in the extraction of the worlds two largest resources of platinum, the Merensky Reef and the UG2 Chromitite Layer. The total cost of mining and processing UG2 ore is currently considerably lower than that of Merensky ore. Jones[2] (1999) lists the following reasons for this difference in costs:

1. The relative density of Merensky ore (D; 3,2) is lower than that of UG2 ore (D; 4.3). This makes UG2 mining costs lower.
2. Crushing and milling of UG2 ore requires less energy because it is more friable.
3. Floatation of Merensky ore requires the use of a talc depressant, at additional cost.
4. UG2 concentrate contains a higher grade of platinum than Merensky concentrate. Less smelting costs are thus incurred for UG2 ore.

The method of mining adopted by a producer also has a significant bearing on cost. Open cast mining, for example, is far cheaper (per ton of ore extracted) than underground operations. Amplats has large reserves of Platreef available for open cast mining. Such operations, when required, can significantly reduce its operating costs. In addition, there is a direct relationship between depth of underground operations and cost.

Deeper mines require far greater infrastructure and energy than shallow mines. This is clearly illustrated by the Northam Platinum Zondereinde Mine's operational costs. Mining at Zondereinde occurs at depths exceeding 2000 m, and is by far the deepest platinum operation in the world. Due to this depth the mine has had to adopt highly specialised engineering solutions to cope with problems such as excessive virgin rock temperatures (VRT's). Viring (1998) reports a VRT at shaft bottom of 75 °C. This requires the use of specialized cooling systems at extremely high cost. Figure 7.1 clearly shows Northam at the top end of the cost curve. Conversely, Lonplats has the shallowest average depth of mining of all SA producers and is the lowest cost producer. The choice of layout for developing and stoping operations within a mine also plays a large role in cost incurred. Producers are constantly involved in research and development aimed at finding optimum layouts.

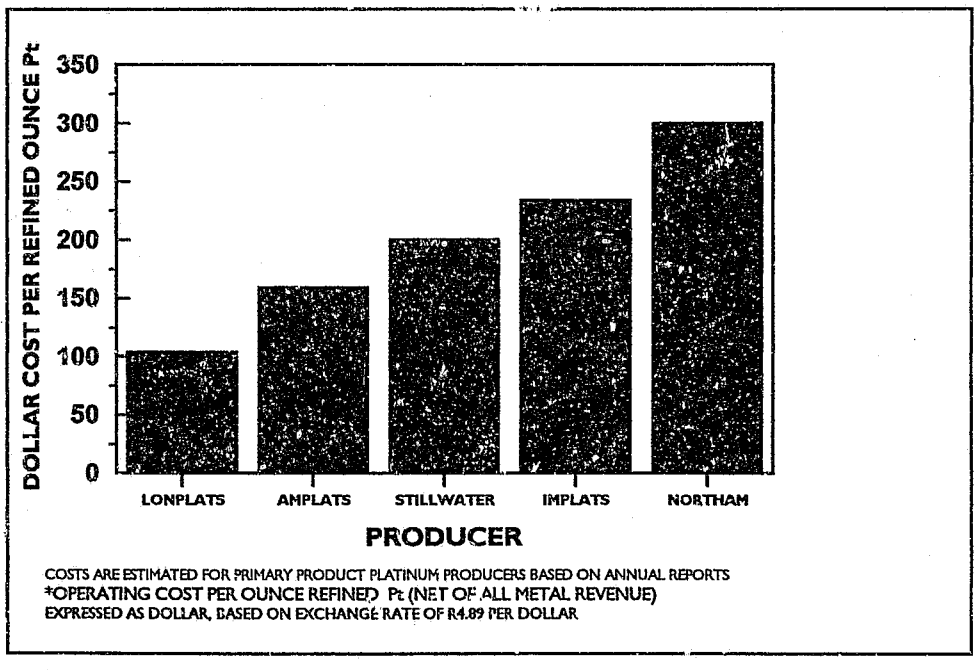


Figure 7.1 An estimated cost curve for major primary product platinum producers (1998)

7.1.2 Processing of ore

Once ore has been extracted, a further set of costs must be incurred to process it and derive a refined platinum product. In the case of PGM production such processing involves a number of steps. Each step is designed to increase the grade of the valuable components and remove the unwanted material (gangue). This process is as follows:

1. **Comminution (milling):** Mined ore undergoes comminution and a gravity concentrate is derived.
2. **Concentration:** The gravity concentrate is fed into tanks in which sulphides are concentrated by floatation.
3. **Smelting:** This process involves the melting of concentrate at high temperatures to produce two liquid phases. A lighter (D; 2,7 to 3.3) unwanted, silicate and iron-rich slag and a denser (D; 4.8 to 5.3) matte. The matte is rich in base and precious metals.
4. **Converting:** This process removes unwanted iron and sulphur through oxidation (blowing air over molten matte). A converter characteristically produces a matte consisting of primarily of Ni_3S_2, Cu_2S and FeS, with a density of about 6.
5. **Base Metal Refining:** Copper and nickel, in various forms are removed through a sulphuric acid leach route. The leach residue makes up a high grade PGM concentrate.
6. **Precious Metal Refining:** This is the last step in ore processing, and involves the extraction of individual precious metals (including pt) from the leach residue.

Table 7.1 below illustrates the increase in valuable components at each step of PGM-ore processing. This table also shows the approximate loss of precious metal at each step.

TABLE 7.1 Increase and loss of precious metal grade during each stage of PGM ore processing (data is sourced from Jones[2], 1999)

MATERIAL	GRADE	APPROXIMATE LOSS OF PRECIOUS METAL*
Mined ore	0.0005% (5 g/t)	Very difficult to estimate. Dependent on accuracy of estimation of reserve grade and ore extraction. Can be as high as 20%.
Concentration	0.015% (100 - 400 g/t)	15%
Convertor matte	0.2%	2 - 5%
PGM concentrate	30 - 65%	1%
Refined metals	99.95%: Pt, Pd, Au 99.90%: Rh, Ru, Os	

*This is an estimated figure based on losses for SA producers.

Each platinum producer attempts to maximise profits by minimising costs incurred at each step of the process and maximising recoveries. A balance between cost of processing and the amount of platinum the producer is prepared to loose must be achieved for each operation.

7.2 Legislation

Demands of legislation imposed on producers by Governments places an ever increasing burden on cost and feasibility of mining operations.

The most inhibiting legislation, currently, involves environmental management and rehabilitation of mining operations. Such legislation has caused producers to critically evaluate the effect of their operations on the environment. This effect must be monitored by the mining operation and is overseen by Government. As populations become more aware of the degeneration of the global environment, increased pressure is put on "clean" mining practices. Currently most operations are required to provide an impact assessment of the potential damage an operation will cause. This must be followed by an environmental plan of how they propose to manage and contain this damage. Most governments require

producers to make regular contributions to a fund which is used for the rehabilitation of expired operations. A producer cannot receive "closure" for an operation until authorities are satisfied with the standard of rehabilitation. As regulations become stricter "environmental costs" demanded of producers become greater. Such costs may render a potential operation not viable.

Legislation involving Mineral rights, also has an inhibiting effect on producers. A new "green paper" proposed by the SA government in 1997 is aimed at "unlocking idle mineral rights" (Forrest, 1998). This proposed legislation will involve a minerals rights tax aimed at discouraging the hoarding of mineral rights by large mining houses. It will encourage the sale of these "unused" rights to the state and the increased exploitation of available reserves. Ballington (1999) reports that "Amplats has already identified certain mineral rights that are vulnerable" and expect the proposed law to be passed in the middle of 2000. This threat mayl cause the expansion of Amplats operations and the sale of certain of it's smaller properties.

7.3 Technical Advancement

Technological advancement in a number of areas of mining, processing and beneficiation of platinum can assist in improving efficiency and lowering cost. Continuous research and development by producers, mining suppliers, academic institutions and other research centers, results in ever improving technologies. Mining operations continuously adopt new technology to allow for, faster, cleaner, less labour intensive extraction at greater depths. Implats have a specialised division within their mining operations which is dedicated to testing all new technologies available to mining. One of their current projects is aimed at improving ore extraction methods and finding alternatives to traditional drilling and blasting. Jagger (1999) reports that the Oscillating Disc Cutter, Mini Disc Cutter, Selective Blasting and Diamond Wire Cutting are methods currently being

tested. Advanced technology applied to processing improves the recoveries of PGM's and base metals from ore. Aquarius's new Kroondal Mine has improved methods of separating waste material from ore, using dense media separation (DMS) technology. This technology was recently developed in conjunction with Mintek (Evans, 1998). Improvements in the various forms of platinum beneficiation, have lowered costs of final products and increased consumer preference for platinum. An example is the research undertaken by Mintek to improve alloys for jewelry. Taylor and Biggs (1999) report on the development new coloured platinum alloys and platinum-gold composites.

7.4 Platinum as a Main-Product or By-Product

Producers of platinum as a main-product, mine deposits in the Bushveld Complex (BC), Great Dyke and Stillwater Complex. All other producers (e.g..; Norilsk, Inco and Falconbridge) produce PGM's as a by-product of base metal mining. These producers are dependent on the state of the market and price of their main product (usually nickel or copper). Primary producers need to consider the prices of all the individual PGM's comprising their "basket" of precious metals. Such an assessment of grade is called a matte evaluation and varies considerably over time, between ore bodies and between mines. Table 7.2, below shows a matte evaluation for the annual production of 1 Moz PGM+Au from "typical" BC Merensky ore. The evaluation is based on average 1998 metal prices. Platinum and palladium constitute over 80% of precious metals in most BC and Stillwater ores. The matte valuation illustrates the importance of platinum i.t.o. revenue earned by BC complex producers. Copper and nickel, in this ore type, only constitute about 0.5% of total revenue earned.

TABLE 7.2 A hypothetical matte evaluation

COMMODITY (PERCENTAGE OF PRECIOUS METALS)	PRICE (AVERAGE 1998 DOLLARS PER oz)	VALUE - M RANDS (OF 1 Moz PGM+Au RECOVERED FROM MERENSKY ORE)
PLATINUM (60)	410	246
PALLADIUM (25)	130	33
TOTAL		**279**
RHODIUM (3)	1,000	30
RUTHENIUM (6)	40	2
IRIDIUM (1)	220	2
TOTAL		**303**
GOLD (5)	370	19
TOTAL		**322**
COPPER (500 oz)*	0.06	0.3
NICKEL (800 oz)*	0.17	1.4
TOTAL		**324**

*amount of base metal recovered, for every 100 oz's of PGM+Au produced

7.5 Labour

Labour involved in platinum production is an important factor affecting both availability of platinum and consistency of supply. The labour force employed in platinum operations is, currently, most greatly affected by Labour Unions. These unions are particularly strong in South Africa and are responsible for significant disruptions in mining operations annually.

Shortage of labour is also of concern to producers. The HIV epidemic is forecast to have a significant effect in reducing the labour force available to SA platinum producers. The virus, for which there is currently no cure is rapidly infecting a large proportion of the labour force. Jones (1999) estimates that within five years it will account for a 10% reduction in available labour per annum. The costs of medical treatment and replacement labour are likely to seriously affect the platinum industry.

7.6 Political Stability

The political stability of a country is a crucial factor in the potential for production of a commodity. A politically unstable country is likely to discourage producers. Capital investment required for the initiation of operations is far more likely to be directed to stable countries. Investors are most reluctant to invest capital which may be lost during civil unrest, government takeovers and economic instability. Exploration aimed at defining future platinum resources in central Africa, for example, is severely hampered by persistent civil and political unrest in many target countries.

7.7 Exploitation of Reserves

Chapter 8 provides an overview of resources and reserves available to platinum producers world wide. As these reserves are exploited, the need for new replacement reserves becomes greater. Reserves are also affected by expansion of mining operations to meet ever increasing demand. Platinum producers typically commence operations on ore which carries the highest grade, is easy to extract and can be processed at the lowest cost. As these deposits become exploited producers are forced to consider less favourable ore and there is increased pressure to find and prove new resources. It is estimated that, at current production rates, the worlds largest resource can continue mining (to a depth of 1200 m) for a further 50 years. All major producers need to continuously satisfy consumers of a steady future supply. To this end they are continuously involved in exploration activities aimed at finding new resources and proving reserves around current operations. In addition, high prices and competition drive the exploration activities of competitors. The author believes that there is currently sufficient world reserves available to meet demand. Without constant exploration, however, this situation can easily be reversed.

7.8 Production "Bottle-Necks"

As mentioned above there are a number of distinct steps in the process of converting platinum in ore to pure platinum (see figure 7.2 below). Complications incurred during any of these steps will result in a hold up in production. All such steps are therefore considered "bottle necks" with the potential to disrupt supply. There are numerous examples of complications occurring at "bottle-necks". Hoisting of ore from a shaft, for example, can be disrupted by a power cut, flooding, a mechanical fault, a shaft accident or any other unforeseen. Virtually all bottle-necks are affected by labour, water and power availability.

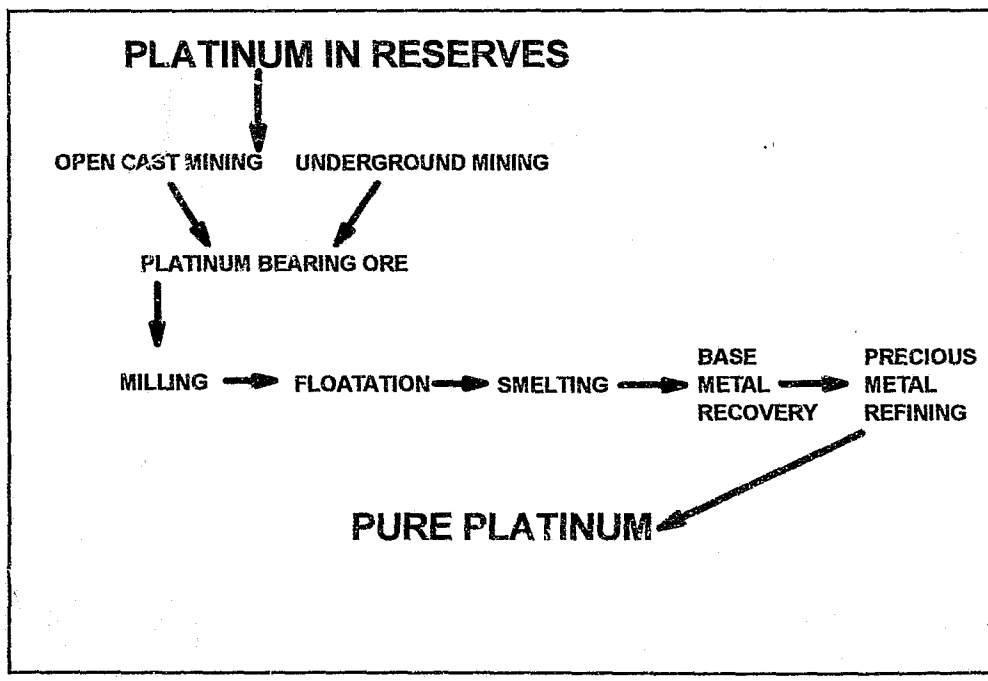


Figure 7.2 "Bottle-necks" in the production of platinum

Supply can be estimated by calculating the maximum through-put capacity of any one of the bottle-necks, and subtracting the loss caused by disruptions. A concentrator, for example, may have a maximum capacity for handling 200 000 t of milled ore per month. It may therefore have a total theoretical capacity for producing a monthly concentrate which contains 900 kg* of PGM. The maximum total production for the concentrator would be 10 800 kg of PGM per annum, or 29.6 kg per day for 365 days (assuming the concentrator worked continuous 24 hour shifts). The total number of shifts lost to disruptions (strikes, power cuts, maintenance shifts etc.) may amount to 15 for a year period. This would mean a loss of 444 kg from the theoretical maximum annual production. The total platinum supply originating from this operation can therefore be estimated at 10 356 kg, for this particular year.

7.9 Summary

World supply of platinum (accounted for in chapter 8) is dependent on production. In order to meet escalating world demand, production must increase persistently. This requirement is often restricted by the constraints discussed above. Platinum market analysts must consider all disruptions to production in their estimation of annual world supply. Forecasting of supply figures should focus on the volume of commodity passing through bottle-necks.

*Based on a grade of 5 g/t

8 WORLD PLATINUM SUPPLY

World platinum supply is primarily dependent on; sustainable and minable resources, recoveries, metallurgical solutions to complicated ore types and, rate and consistency of production. Factors which affect production include: availability of water, power and labour, the social and political stability of a producing country, climate, security, legislation and cost. This chapter presents an overview of the worlds known platinum resources and provides an account of their feasibility in terms of production. All current production is tabled and a forecast of future production, based on expansions and new mining activities, is proposed. Finally an estimate of total world supply is derived. The aim of the chapter is to account for the current and future supply of platinum available to the world market.

Data used in the estimation of platinum resources, production and supply has been sourced from all available information. Estimates are derived from annual reports of producing companies, market analysts and current authors. Although care has been taken to authenticate figures, secrecy surrounding certain producers and their reserves, may have caused some inaccuracies within figures. All data referred to as "current" pertains to 1998. Annual estimates are estimates pertaining to output occurring within the period 01 January to 31 December of any given year.

8.1 World Resources

Platinum resources (or occurrences of platinum) include all known ore deposits containing platinum. Resources described below, include all "*in-situ* mineralisation estimates" as defined under Mineral Resources of the South African Code for Reporting of Mineral Resources and Mineral Reserves (SAMREC Draft Code, 1999). Only resources that currently support mining activities are included.

"Platinum bearing resources are invariably related to, or contained within, either differentially stratified and layered or massive mafic to basaltic magmatic complexes that have intruded stable cratonic or continental rocks at various periods in geological time" (Vermaak, 1995). Naldrett (1989) recognizes two categories of platinum deposits; PGM dominated and Ni-Cu dominated.

The viability of depletion of resources belonging to the first category depends directly on the current market prices of individual PGM's (as explained in chapter 7). Known (discovered) resources in this category include: the Merensky Reef, the UG2 Chromitite Layer and the Platreef of the Bushveld Complex (BC), South Africa; deposits of the Great Dyke in Zimbabwe; the Stillwater Complex of the USA; and the Lac des Isles deposit of Canada.

The viability of resources belonging to the second category depends on the current market prices of base metals, PGM's in this case are merely by-products. Known resources in this category include; Noril'sk-Talnakh in Russia, the Finnish deposits, the Jinchuang deposits of north-west China, and the Duluth Complex of the USA.

Alluvial or placer deposits make up a third category of resources that are derivative ore bodies of base metal and PGM dominated deposits. Vermaak (1995) makes mention of "hundreds of small placer deposits" . Apart from operations in the Urals, there is currently very little platinum output emanating from any of these deposits. The principle known world resources are described in more detail below. The localities of these resources are illustrated in Figure 8.1.

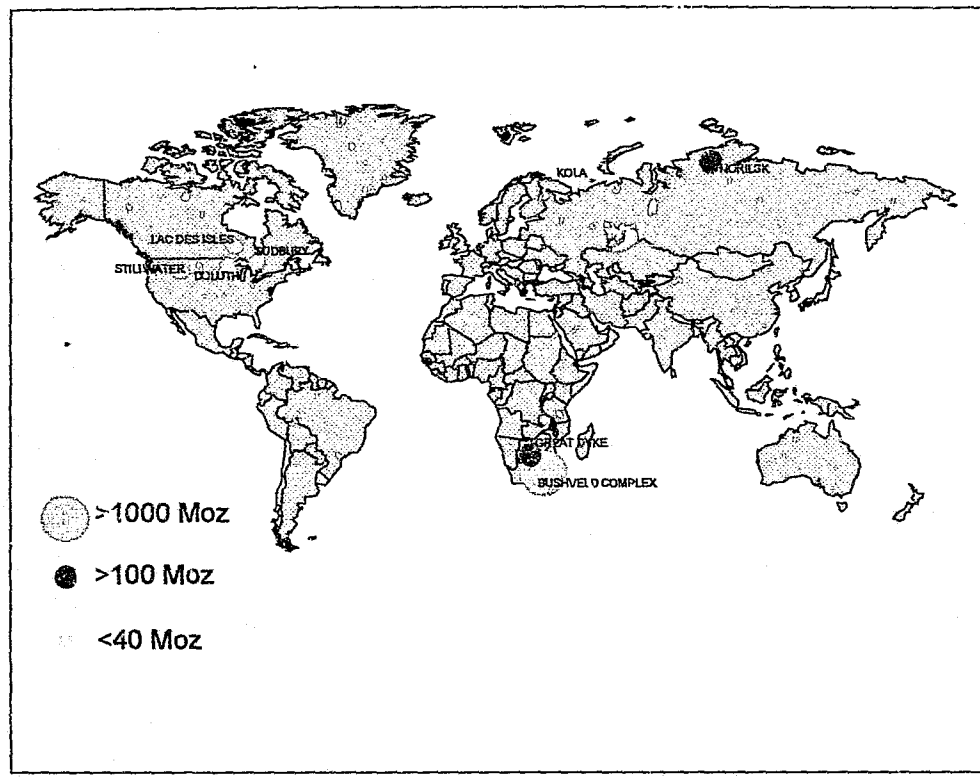


Figure 8.1 The geographic distribution of significant world platinum resources

8.1.1 The Bushveld Complex

The Bushveld Complex (BC) is "the largest repository of PGM in the world" (Viljoen, 1998) containing some 85% of the worlds platinum group metal (PGM) resources. The main Complex has an elliptical form measuring 370 km in an east-west direction and 365 km in a north-south direction (covering an area of some 60 000 km^2). It consists of a layered intrusion of dense ultramafic rocks overlain by light-coloured gabbro-noritic rocks (Viljoen, 1998). Most of South Africa's platinum resources are contained within sulphide-rich horizons (the Merensky Reef, the UG2 Chromitite Layer and the Platreef) occurring within the Critical Zone of the Complex. These reefs have an average dip of about 15°. Platinum is one of six PGM's occurring in association with copper (Cu), nickel (Ni) and gold (Au) in the BC. Two platinum rich horizons; the

UG2 Chromitite Layer and the Merensky Reef, are currently the largest resources for PGM, Au, Cu, and Ni within the BC. Table 8.1 provides current estimates of minable quantities of PGM and platinum for sectors of the BC already explored. The average grade of 3PGM+Au varies from mine to mine and between reefs, but is in the region of 4,5 to 8 g/t for most mining lease areas (Vermaak, 1995). The proportion platinum of PGM is usually in the region of 50% for most ore bodies within the BC (Heimstra, 1985). Vermaak (1995) estimates the total PGM content in this resource, to be in the order of 2105 Moz. This would suggest a platinum content, for the BC of about 1064 Moz.

Table 8.1 Proprtion platinum of PGM for reef types and regions within the Bushveld Complex (after Vermaak, 1995). Calculated *in situ*, to a depth of 1200 m.

MERENSKY AND PLATREEF *IN-SITU*	**PGM (000oz)**	**PLATINUM (000oz) (percentage of PGM)**
W. BUSHVELD	491,649	287,202 (58,4)
E. BUSHVELD	349,414	195,357 (55,9)
POTGIETERSRUS	211,593	90,668 (42,8)
UG2 *IN-SITU*		
W. BUSHVELD	548,646	285,910 (52,1)
E. BUSHVELD	503,660	205,327 (40.8)
TOTAL (t)	**65,473**	**33,094**
TOTAL (Moz)	**2,105**	**1,064**

In addition to the above mentioned resources there are a number of other identified South African platinum deposits which are presently not viable. These include:

- The Insizwa nickel-copper deposits, near Kokstad in the Eastern Cape.

- The Uitkomst nickel-copper deposit in the Carolina District of Mpumalanga.
- The other chromitite layers in the Lower and Critical Zones of the BC.

8.1.2 Norilsk and Talnakh

Russian resources include: Norilsk-Talnakh, Kondjorskoye (placer deposits), Sakha (placer deposits) and the Ural Mountains (alluvial deposits). Although the alluvial deposits currently contribute to annual Russian production, they have been exploited for some 150 years and are nearing exhaustion (Viljoen, 1998). Almost all future production will be centered around the Norilsk and Talnakh deposits and these are therefore considered as the relevant Russian resources. Norilsk and Talnakh are situated in the Taymyr Region of northern Siberia. Two main ore-bodies are identified in this area. They are the Norilsk-Karealakh fault, and the Octyabrsk Ore Body occuring to the west of Norilk (Vermaak, 1995). Both ore bodies deepen in a northerly direction and mines vary in depth from 300 m to 2000 m below sea-level. The ore occurs as massive and disseminated Ni-Cu. The PGM grade of the ore is very difficult to estimate, due to the variability of the ore body and the scarcity of information received (Viljoen, 1998). Estimates of average grade for the resource range from 3,8 g/t (ISMI paper - Vermaak,1995) to 7,85 g/t (Johnson Matthey, 1994). The latest estimate by Forrest (1998) of an average grade of 7.2 g/t PGM for all Norilsk-Talnakh mines is believed, by the author, to be most accurate. The estimates of resource size, for *in-situ* PGM's also vary from 6 220 696 kg (Buchanan, 1979) to 17 875 200 kg (Vermaak, 1995). For consistency, the estimate by Vermaak (1995), of 651 Moz of PGM resource is used. This suggests a total (remaining) Russian platinum resource of 128 Moz, as illustrated in Table 8.2 below.

Table 8.2 Platinum resources in Norilsk and Talnakh, Russia (after Vermaak, 1995). Calculated *in situ*, to a depth of 1200 m.

ORE BODY	PGM	PLATINUM (000oz) (percentage of PGM)
TALNAKH	416,995	75,638 (18.1)
NORILSK	234,250	52,492 (22.4)
TOTAL (t)	**20,256**	**3,985.3**
TOTAL (Moz)	**651**	**128**

8.1.3 The Great Dyke

The Great dyke is a "unique, highly elongate, linear, graben like mass of ultramafic rocks" (Viljoen, 1998) situated in central Zimbabwe. It has an age of 2461 My and consists of four contiguous, narrow, layered, ultramafic complexes aligned NNE along 550 km of strike. The width of these complexes ranges between 5 and 12 km. Most of the PGM mineralisation is contained within a 1 to 5 m thick pyroxenite and websterite layer, which contains up to 7% sulphide. This "zone" is known as the Main Sulphide Zone and is persistent over the entire Dyke. The average thickness of the mineralized zone is between 1.5 and 2 m, with platinum grades of over 3 g/t. PGM's occur as alloys associated with phyrhotite and minor amounts of pentlandite, chalcopyrite and pyrite. The average proportions of principle PGM+Au are; 52% platinum, 35% palladium and 9.5% Au. The total Ni and Cu content is 0.83% (Viljoen, 1998). The largest resources of PGM in the Great Dyke are concentrated in the Hartley Norite Complex. This ore resource is estimated at 2.3 billion tonnes with an average grade of 3.6 g/t 3PGM+Au (Nutt, 1999). Vermaak (1995) estimates the total potential resource of platinum to be about 2570 Mt over a stoping width of 1m. This would suggest a platinum resource, for the Great Dyke of 179 000 oz, as illustrated in Table 8.3 below.

Table 8.3 Calculated resources of platinum for the Main Sulphide Zone within regions of the Great Dyke (data sourced from Nutt 1999, Vermaak 1995 and Viljoen 1998). Calculated *in situ*, to a depth of 1200 m.

MAIN SULPHIDE ZONE *IN-SITU*	PGM (000 oz)	PLATINUM (000 oz) (percentage of PGM)
MUSENGESI	21	12 (57)
DARWENDALE-SEBAKWE	239	133 (56)
SELUKWE	40	22 (55)
WEDZA	21	12 (57)
TOTAL	**10,091 000 t**	**5,656 000 t**
TOTAL (000 oz)	**321**	**178.9**

8.1.4 Resources of the USA

Stillwater Complex

The Stillwater Complex is a 2700 My old, differentially layered sequence, situated in Montana in the USA. It consists of 7400 m of ultramafics, peridotites and bronzitites (Vermaak, 1995). PGM's are recovered from the JM Reef (named after Johns Manville Corporation, the discoverers). The Reef has been identified over a 45 km strike length and dips at 50 to 90 degrees in a northerly direction (Stillwater Mining Company, 1999). It has an average thickness of 1,83 m. Two main mineralized areas, Stillwater Mine and East Boulder Project, have been identified with a combined strike length of 12.07 km (Vermaak, 1995). Vermaak (1995) estimates the grades for the complex to average 4.65 g/t platinum, 14.09 g/t palladium, 0.14% Cu and 0.23% Ni. Stillwater Mining Company (1999) present proved reserves for their two mining areas (Stillwater Mine and East Boulder Project) of 26 Moz PGM. They estimate reserves of 37.1 Mt at a grade of 21.1 g/t PGM. Resources presented in Table 8.4 below are estimated for the JM Reef within the entire Stillwater Complex.

Duluth

The Duluth Complex covers an area of 280 km by 40 km, from Duluth on Lake Superior to the Canadian border. It is a large lopolithic mass of ultramafic and mafic rocks with an age of 1100 My. The deposit comprises sheetlike and cone shaped intrusions ranging in composition from anorthositic to ferrogabbroic. Net-textured or disseminated ore bodies of high sulphide content are found in "basins" in the floor (Vermaak, 1995). These mineralised zones dip, on average, at between 15 and 20 degrees. The average grades are 0.66% Cu, 0.20% Ni and 0.124g/t PGM. The latter is split at 20.52% Pt, 76.43% Pd, 1.42% Rh, 1.18% Ru, 0.28% Os and 0.17% Ir (Vermaak, 1995). The total resource of "copper-nickel ores" is estimated to be in the order of 11 000 Mt (containing some 280 000 kg of platinum).

Crillion La Perouse

The Crillion La Perouse Complex lies under the Brady Glacier in the Fairweather Range of Alaska. Massive and disseminated copper-nickel ores occur in peridotite and gabbro at the base of a 10 km thick synformal layered intrusion. Vermaak (1995) estimates a resource of 90.7 Mt of ore with average grades of 0.5% Ni and 0.3% Cu. It is estimated that the disseminated ore contains 0.19 g/t Pt and Pd and the massive ore 1.31 g/t in the ratio 1:1.125 (Vermaak, 1995). A platinum resource of 24 000 kg is estimated for this resource.

Table 8.4 Resources of PGM within the USA (data sourced from Vermaak 1995, Viljoen 1998 and Stillwater Mining Company 1999). Calculated *in situ*, to a depth of 1200 m.

IN-SITU	PGM (000 oz)	PLATINUM (000 oz) (percentage of PGM)
STILLWATER (JM REEF)	213,096	45,134 (21.2%)
DULUTH	44,525	8,999 (20.2%)
CRILLION-LA PEROUSE	1,750	777 (44.4%)
TOTAL (t)	**8,056**	**1,711**
TOTAL (Moz)	**259**	**55**

These estimates suggest the total PGM content for US resources, to be in the order of 259 Moz, with a platinum resource of about 55 Moz.

8.1.5 Canadian resources

Sudbury Basin

The Sudbury Basin is a 60 by 27 km wide, nickel and copper rich deposit, situated near Lake Superior in the Grenville Provinces of the Canadian Shield (Viljoen, 1998). Ore bodies within the Basin are contained in a discontinuous sublayer to a "Nickel Irruptive" which intruded some 1850 My ago. Both the Basin and the Irruptive, are believed to have resulted from a meteorite impact. The sublayer magma was rich in sulphides and contains inclusions of peridotite, pyroxenite and gabbro (Viljoen, 1998). This gave rise to various structurally controlled ore bodies which are the worlds largest source of nickel, in addition to by-product resources of copper, cobalt, iron, platinum and eleven other elements. Known ore bodies contained within the sublayer include; the Creighton Ore Zone and the Strathcona Deposit. Other associated ores are contained within the Frood-Stobie orebody (in an offset dyke) and the Sudbury Breccia. High grade ores contain concentrations of 3.5% nickel and 2% copper (Viljoen, 1998). The Basin contains a total known ore

reserve of 930 Mt (Viljoen, 1998) with an estimated PGM grade of 1.07 g/t* (Vermaak, 1995). The average proportions of PGM are calculated at; 43.25% platinum, 44.52% palladium, 4.08% ruthenium, 5.36% rhodium, 1.89% iridium and 0.90% osmium. The total platinum resource estimated by Vermaak (1995) for the Sudbury Basin amounts to 5 112 000 oz.

Lac des Isles Deposits

The Lac des Isles Deposits occur 80 km northwest of Thunder Bay in western Onterio. The Lac des Isles Complex forms part of a swarm of ultramafic bodies and consists of a vertically zoned igneous plug (Vermaak, 1995). The plug is divided into portions representing different intrusions of layered mafic and ultramafic rocks. Sulphide rich ore is concentrated in the "C" Discovery Zone and Roby Zone. The Roby Zone is estimated to contain; 0.214% nickel, 0.205% copper and 6.4 g/t platinum and palladium (with a ratio of 1:9.39, Pt:Pd). These deposits contain an estimated platinum resource of 411 000 oz (North American Palladium Ltd., 1999)

Table 8.5 Resources of PGM in Canada's Sudbury Basin and Lac Des Isles Deposits (data sourced from Vermaak, 1995 and North American Palladium Ltd., 1999) Calculated *in situ*, to a depth of 1200 m.

IN-SITU	PGM (000 oz)	PLATINUM (000 oz) (percentage of PGM)
SUDBURY	11,799	5,112 (43)
LAC DES ISLES	3,697	411 (11)
TOTAL (t)	**878**	**343**
TOTAL (000 oz)	**15,496**	**5,523**

Estimates suggest the total PGM content for Canadian resources, is about 15 Moz oz, with an estimated platinum resource of 5.5 Moz.

*this figure includes a 20% recovery loss

8.1.6 Other deposits (supporting platinum mining activities)

Finland

Finland's known platinum resources are contained within a number of variously sized Cu-Ni deposits. Vermaak (1995) lists these as; Archaen deposits, early Proterozoic layered intrusions, the Outokumpu ultramafic complex of northern Karelia (1970 My), the Svecokarelian ultramafic intrusions (1990 to 1860 My) and the post Svecokarelian dolerite dykes (1959 to 1560 My). Most of these resources have no current reserves and are described as subeconomic. Estimated total resources for PGM and platinum are shown in table 8.6. These figures are very rough estimates calculated by Vermaak (1995).

China

Most of China's resources are contained within the Jinchuang copper-nickel deposit (1509 My). This is a nickel copper dominated deposit hosted in ultramafic intrusions. Ore bodies are 6 500m long and 300m wide and are structurally controlled by north-west faulting. Three economically viable ore bodies are currently known Nos 1, 2 and 24. Although massive sulphide ore occurs in No 2 ore body, the most common ore-type is a continuous base metal sulphide network occurring as a matrix around olivine crystals. The total deposit is estimated to contain an average of 1.68% nickel, 1.17% copper, 0.7 g/t platinum and 0.23 g/t palladium (with a ratio of 1:2.4, Pd:Pt). The deposits are estimated to hold a platinum resource of about 8.6 Moz (Vermaak, 1995).

The Urals

Platinum resources occur in placer deposits in the Urals. These deposits consist of eluvial and terrace gravels of different ages and are found in the districts of; Tagil, Issovak, Kitlim-Kama and Soarsersk. The main ore body occurs in a sandy layer known as the "peskis". This layer is covered by an average of 11 m of overburden and contains PGM grades of

between 0.31 and 2.8 g/t. Vermaak (1995) suggests that the main reserves of these deposits are close to exhaustion.
Other less significant deposits can be found in fossil placers of Columbia, Australia, Ethiopia, Tasmania and Borneo.

Table 8.6 Other resources of PGM, which support mining activities (after Vermaak, 1995). Calculated *in situ*, to a depth of 1200 m.

IN-SITU	PGM (000 oz)	PLATINUM (000 oz) (percentage PGM)
JINCHUANG	13.6	8.6 (63)
FINLAND	486.7	123.4 (25)
TOTAL (000 oz)	**500.3**	**132**

The author estimates the worlds total known resource of platinum to contain 44,329 t or 1,564 Moz (see Table 8.7 below). Figure 8.2. illustrates the distribution of known world resources by country.

Table 8.7 Estimated *in situ* world resources of platinum

REGION / SOURCE	DEPOSIT	OUNCES OF PLATINUM (M) IN KNOWN IN SITU RESOURCES*
SOUTH AFRICA	Bushveld Complex	**1,064 (68.%)**
RUSSIA	Norilsk and Talnakh	**128 (8.2%)**
ZIMBABWE	Great Dyke	**179 (11.4%)**
USA	Stillwater, Duluth, Crillion La Peruse, New Rambler	**55 (3.5%)**
CANADA	Sudbury, Lac des Isles	**5.5 (0.4%)**
OTHERS	Jinchuaung, Finland	**132 (8.5%)**
TOTAL		**1,564**

* resources which are currently being exploited

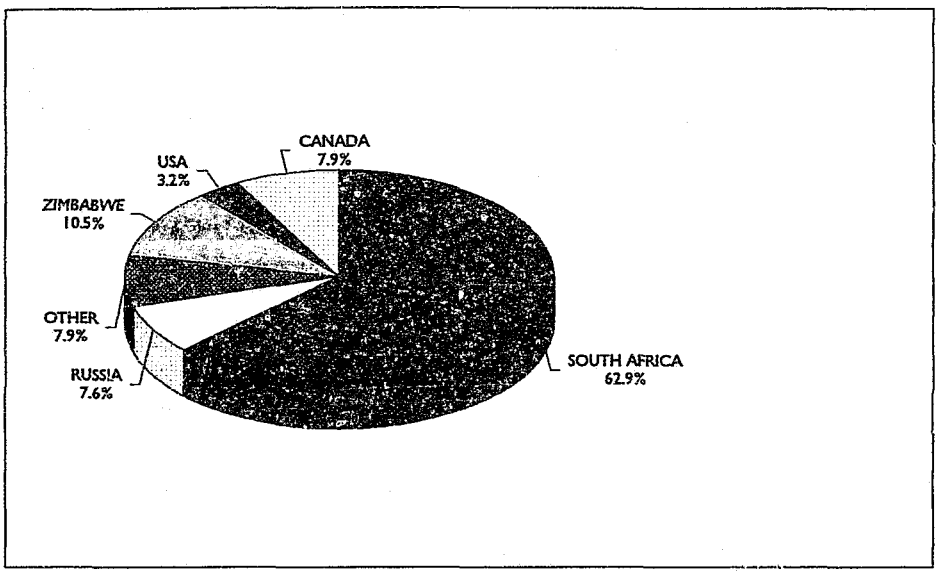


Figure 8.2 The distribution of known world resources of platinum

Figure 8.3 illustrates the average split (or basket) of metals contained in all known world resources. It is interesting to note that platinum accounts for approximately 50% of the PGM's in known deposits.

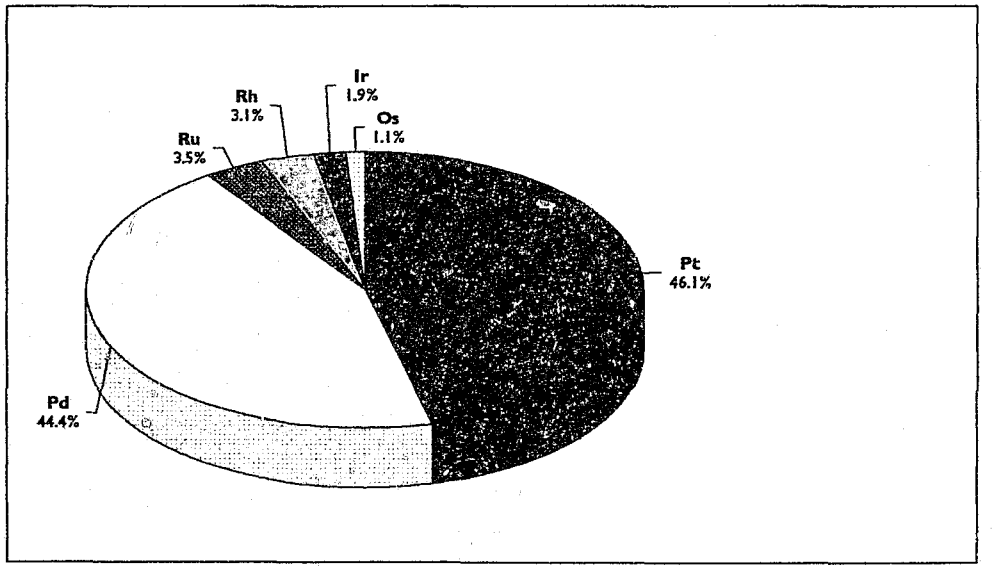


Figure 8.3 Average individual PGM percentages in known world resources (data sourced from Vermaak, 1995)

8.2 Current Supply

Current world platinum supply is estimated by various market analysts and commentators on an annual basis. Total annual supply is related to produced ounces of the metal, but is measured as the quantity released onto the market. Platinum production may be primary (refined from ore) or secondary (recovered from scrap). In some instances producers withhold annual production or augment annual production, with ounces produced previously. Total world supply is described under Production by Region, Secondary Supply and Total Supply Account, below.

8.2.1 Production by region

South Africa

All South African production currently emanates from the Bushveld Complex resources (the UG2, Merensky and Plat Reefs). The main companies involved in platinum production in South Africa are listed below in order of size:

Amplats, who are responsible for 50% (about 1.9 Moz) of South African PGM production, exploit approximately 14 Mt of Merensky, 4 Mt of UG2 and 3 Mt of Plat Reef within their lease areas annually (Forrest, 1998). They are responsible for the following operations: Rustenburg Platinum Mines (made up, currently, of Rustenburg, Union and Amandelbult sections), Potgietersrus Platinum and Lebowa Platinum. The companies PGM's are refined to metal powders or sponges at an inhouse precious metal refinery at Rustenburg. Amplats report a mine output of 22 Mt for 1998. This yielded 1 898 400 oz of platinum (Boyd, 1998). In addition, some 931 000 oz of palladium and 177 000 oz of rhodium were produced (Johnson Matthey, 1999).

Implats, are responsible for 28% (about 1 Moz) of South African PGM production. They have consolidated their Bafokeng and Wilderbeesfontein Mines to operate as a single operation and currently account for a run of mine output of about 14 Mt of ore from 13 shafts (Forrest, 1998). Impala produces final precious metal sponges and powders at a precious metal refinery in Springs (near Johannesburg). Implats report a mine output of 14.5 Mt for 1998 (Mc Mahon, 1999). This yielded 1 052 000 oz platinum.

Lonplats, who are responsible for 17% (about 0.63 Moz) of South African PGM production operate Karee, Western Platinum and Eastern Platinum Mines in the Western Limb of the BC. They produce some 9 Mt run of mine (70% UG2 and 30% Merensky) and refine PGM's to metal sponges at an inhouse precious metals refinery in Brakpan near Johannesburg. Johnson Matthey (1999) report a mine output of 9.2 Mt for 1998. This will yield 1.007 Moz of PGM or about 627 514 oz platinum (Wilkinson, 1998).

Northam Platinum, who are responsible for 5% (about 0.2 Moz) of South African PGM production from the Zondereinde Platinum Mine in the Western Limb of the BC. Zondereinde is designed to have an annual run of mine output of 1.8 Mt per annum (Forrest, 1998). Concentrate produced is toll refined at W.C. Heraeus GmbH in Germany (Vermaak, 1995). The annual operating results show a mine output of 1.74 Mt of ore for 1998 (Wright, 1999). This will yield 322 000 oz of PGM or about 200 000 oz of platinum.

The estimated current production from all South African platinum operations, is presented in Table 8.8, below.

Table 8.8 Current South African platinum production (data sourced from Amplats, Implats, Lonplats and Northam 1998 Annual Reports, Forrest 1998 and Johnson Matthey 1999)

1998 PRODUCTION NAME OF MINE	GRADE (3PGM+Au)	ANNUAL TONNAGE (000)	ANNUAL PLATINUM PRODUCTION (000 oz)
Amplats: (Rustenburg, Lebowa, Potgietersrus)	5.5	21,000	1,898
Implats	8.2	14,500	1,052
Lonplats (Karee Western Plats Eastern Plats)	6.1	9,000	627
Northam	7.8	1,800	200
TOTAL			**3,777**

South African platinum producers accounted for some 3 777 000 oz of PGM in 1998. Figure 8.4, below, shows the holdings of the various platinum producers within the BC.

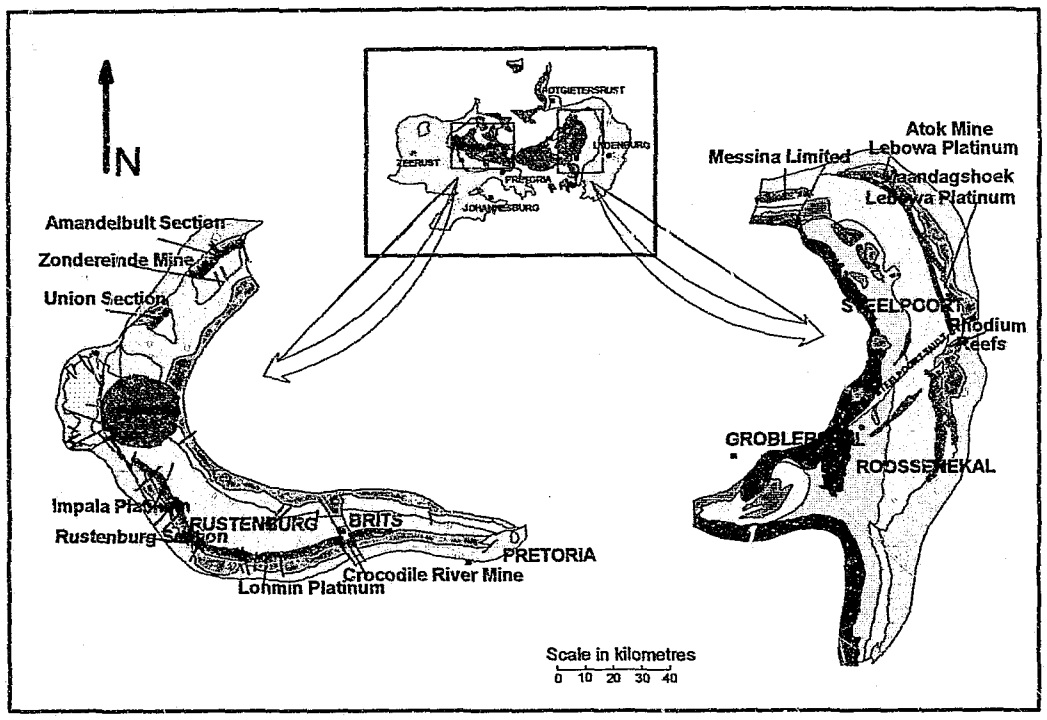


Figure 8.4 South African platinum producers in the Bushveld Complex (blue indicates UG2 suboutcrop and green, mineral rights holdings)

Russia

Russia is the second largest producer of platinum. Forrest (1998) estimates that the bulk of production (95%) emanates from the Norilsk and Talnakh complexes. Operating mines at Norilsk and Talnakh include two open pits, Zapoljarni and Mayak, which are near exhaustion and extremely marginal, and three principle producers Oktyabrysky, Komsomolsky and Taymyrsky (Forrest, 1998). These mines are all controlled by Uneximbank, who have a monopoly in the production of nickel, cobalt, copper and PGM. Production rates currently run at around 13 Mt for the Talnakh Complex and 3 Mt for the Norilsk Complex (Forrest, 1998). Indications are, however, that these rates will be affected by the financial disposition of Uneximbank which is unable to raise sufficient capital for expansion and replacement of extraction (Hochreiter, 1998). As

can be seen in the estimations sited by various authors, the variability in estimation of Russian platinum production is significant;

- Johnson Matthey (1999) estimate that the Norilsk-Talnakh mines produce some 550 000 oz per annum, and suggest that this is currently augmented by a further 300 000 oz from alluvial workings, primarily at Koryak and Kondyor in the far eastern region of Russia.
- Christian[2] (1998) estimates current annual Russian platinum production to be 980 000 oz.
- Hochreiter (1998) estimates current annual Russian platinum production to be 600 000 oz.
- Forrest (1998) estimates current annual Russian platinum production to be 700 000 oz.

The variation in estimation, between 600 000 and 980 000 oz per annum, amounts to 380 000 oz! The author believes that the conservative figure of 700 000 oz (by Forrest, 1998) to be most accurate and has chosen to use this figure as representative of the Russian annual production for 1998.

Table 8.9 Current Russian platinum production (data sourced from Forrest, 1998)

NAME OF MINE	ESTIMATED ANNUAL PRODUCTION OF Pt (000 oz)
Norilsk and Talnakh complexes	500
Alluvial production (primarily from Koryak and Kondyor)	200
TOTAL	**700**

Zimbabwe

Zimbabwe's main platinum resources lie in the Great Dyke, and since 1995 the bulk of platinum has been produced from this complex. Insignificant amounts of platinum, produced as a by-product from nickel mining at Trojan and Shangani Nickel Mines, is the only other source at present (Nutt, 1999). The main companies involved in future and current

platinum production on the Great Dyke are; Anglo American Zimbabwe, Zimplats, Zimasco, Delta Gold and BHP. Estimated production from Zimbabwean Mines is illustrated in Table 8.10 below. Johnson Matthey (1999) report a total Zimbabwean platinum output of 135 000 oz for 1999. The majority of this (some 126 000 oz) was produced at the now closed Hartley Platinum Mine. Johnson Matthey (1999) site recovery and smelting blockages as reasons for the mine not producing its forecast of 150 000 oz. Zimasco's Mimosa Mine is the only other producer currently, with an output of about 19 000 oz (Barnard Jacobs Mellet and Co., 1999).

Table 8.10 Current Zimbabwean platinum production (data sourced from Johnson Matthey 1999, Nutt 1999, Barnard Jacobs Mellet and Company 1999)

NAME OF MINE	ANNUAL PLATINUM PRODUCTION (000)
Hartley Platinum	126
Mimosa	19
TOTAL	**135**

North America (Canada and the USA)

The majority of North American platinum production currently emanates from Stillwater, Sudbury and Lac des Isles. The main companies involved are listed below in order of size:

Inco Ltd, accounting for some 350 000 oz of PGM (Inco, 1999). It is the worlds largest producer of nickel and produces platinum as a by-product from mining operations in Sudbury, Ontario and Thompson, Manitoba. A recent merger with Diamond Fields Resources could see additional by-product platinum production from Voisey Bay, Labrador (Forrest, 1998). Inco's precious metals are refined at Acton in England (Inco, 1999). The author estimates a current annual platinum output of around 150 000 oz.

Stillwater Mining Company, which is the largest producer of PGM's in the western world, outside of South Africa , accounting for some 444 000 oz in 1998 (Stillwater Mining Company, 1999). The company is currently producing about 108 000 oz of platinum and 336 000 oz of palladium. This amounts to 2% and 4%, respectively of world supply for 1998 (Stillwater Mining Company, 1999).

Falconbridge, which is the worlds second largest nickel producer, produces PGM's as a by-product from operations in Sudbury, Ontario and Kidd Creek Copper-Zinc Mine, Timmons. Falconbridge accounts for an annual platinum production of about 30 000 oz. (Forrest, 1998).

North American Palladium Ltd (NAP), in agreement with the Sheridan Platinum Group operate open cast mining in the Lac des Isles Deposit 50 miles north of Thunder Bay, Ontario (Forrest, 1998). Although primarily a palladium producer (73 390 oz pd were produced in 1998), NAP currently accounts for 4 770 oz of platinum (North American Palladium, 1999). In addition the mine produces over 1 Mlb Cu, 800 000 lb Ni and 4,000 oz Au.

Table 8.11 Current North American platinum production (data sourced from Forrest 1998, Johnson Matthey 1999, Stillwater Mining Company 1999, Inco 1999, Falconbridge 1999 and North American Palladium 1999)

NAME OF MINE	ANNUAL PLATINUM (000 oz)
Inco	150
Stillwater	108
Falconbridge	30
North American Palladium	4.7
TOTAL	**292.7**

North American platinum producers accounted for some 292 700 oz of platinum in 1998 (Johnson Matthey, 1999).

Other

China. Platinum production from Jinchuang is assumed to be minimal. Very little information is available regarding production from this operation. It is assumed that annual PGM production is less than 5 000 oz per annum.

Finland. Platinum is produced as a by-product of the following copper-nickel mines which are operated by Outokumpu Oy: Hammaslathi, Hitura, Kotalahti, Pyhasalmi, Stromie, Virtasalmi and Unonos. The country produces a PGM sludge from the Harjavalt Nickel Refinery and the Pori Copper Refinery (Vermaak, 1995). PGM refining is done outside of the country.

"Other" platinum producers are estimated to have produced some 5 000 oz of PGM in 1998.

8.2.2 Secondary supply

Secondary production refers to recovery from scrap. Platinum bearing "scrap" is classified as either "New Scrap" or "Old Scrap". The latter refers to scrap produced in refining and industry. It includes materials such as; slimes, sludges, machining chips, ingot scalpings, grindings, skimmings, drosses, and sweepings. Old Scrap is the principle source of secondary platinum and refers to metal recovered from petroleum processing, the chemical industry, autocatalyst manufacture, glass manufacture, electronics and photographic scrap. Platinum used in auto-catalysts is theoretically non destructible and the worlds retired vehicle population is by far the largest source of secondary supply. It is estimated that half the value of a retired vehicle lies in its catalytic converter. Successful

recycling of converters is dependent on, both the efficiency of collection (dependent on; density of vehicle population in geographic areas, transport cost, lot price of converters etc.), and the recovery technique used. The Japanese have recently improved recovery from about 50% to between 65 and 90%.

The USA is the must active in the recovery of platinum from spent convertors. This is a direct result of stricter emissions controls, which enforce higher "PGM loadings". In contrast, recycling of convertors in Europe is described as "sporadic and inefficient".

Secondary supply of platinum is estimated as the amount of metal recovered from autocatalysts, for the purposes of this "Supply Account". Although other scrap metal is refined and other recycling takes place, it is estimated to constitute a very small and relatively insignificant amount. Johnson Matthey (1999) estimate 405 000 oz of secondary platinum was produced in 1998. An increase of 35 000 oz on the 370 000 oz estimated for 1997, is attributed to "the higher loadings on catalysts collected in North America in 1998". These higher loadings are a consequence of stricter legislation on emmissions control, discussed in more detail in chapter 4. Figure 8.5, below illustrates the annual volume of platinum recovered from convertors during the last ten years (1988 to 1998). It is interesting to note the steady increase in supply, from about 200 000 oz in 1991 to over 400 000 oz in 1998.

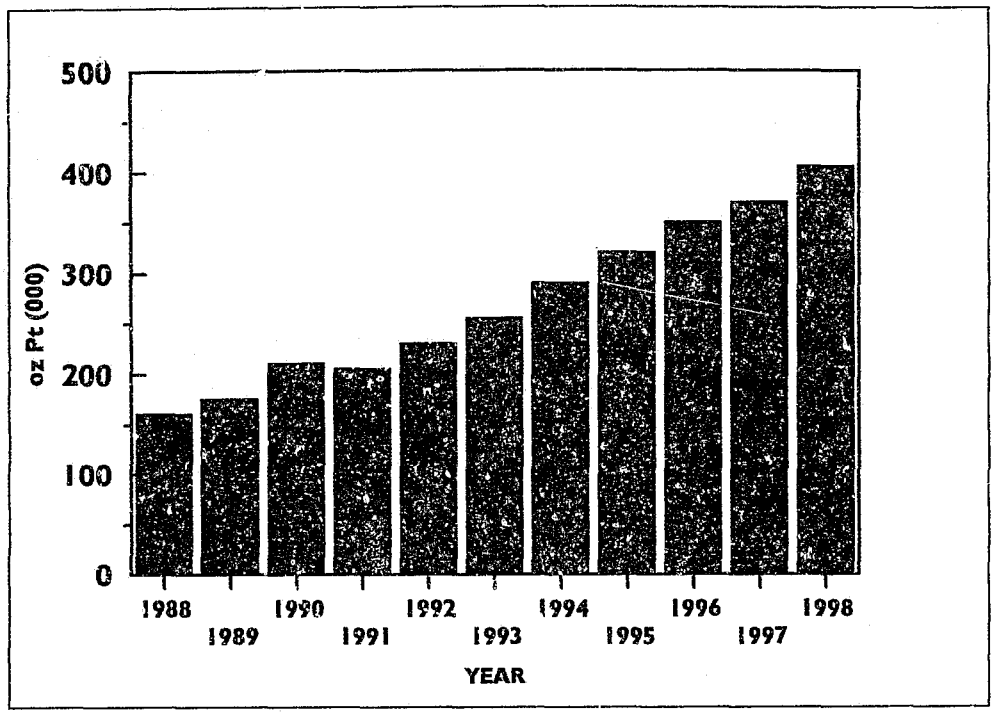


Figure 8.5 Recovery of platinum from autocatalysts (data sourced from Johnson Matthey, 1997 and 1998)

8.2.3 Account of current supply

Annual platinum production from most Western producing regions closely approximates the amount released on the world market annually. Russian supply, however, is completely variable (as explained in chapter 6) and is, currently not related to Russian production. Russian supply, as a result of sales from inventories and production has accounted for 900 000 oz in 1997 and 1 300 000 oz in 1998 (Hochreiter, 1998). This has depleted Russian platinum inventories by an estimated 500 000 oz, in 1998. Most analysts agree that little or no Russian platinum stockpiles will exist after 1998. Table 8.12, below gives an account of the current annual world supply of platinum in 1998.

Table 8.12 Estimated current (1998) world platinum supply

REGION / SOURCE	DEPOSIT (if applicable)	OUNCES OF PLATINUM (000) SUPPLIED IN 1998
SOUTH AFRICA	Bushveld Complex	3,777
RUSSIA	Norilsk and Talnakh	1,300
NORTH AMERICA	Stillwater, Sudbury, Voicies Bay, Kidd Creek, Duluth, Lac des Isles	292.7
ZIMBABWE	Great Dyke	135
OTHERS	Outocumpo, Jinchuang, placer deposits etc.	5
SECONDARY	Spent Autocatalysts	405
TOTAL		**5,914.7**

Figure 8.6 illustrates the increase in world supply of platinum over the last ten years (1988 to 1998), by region.

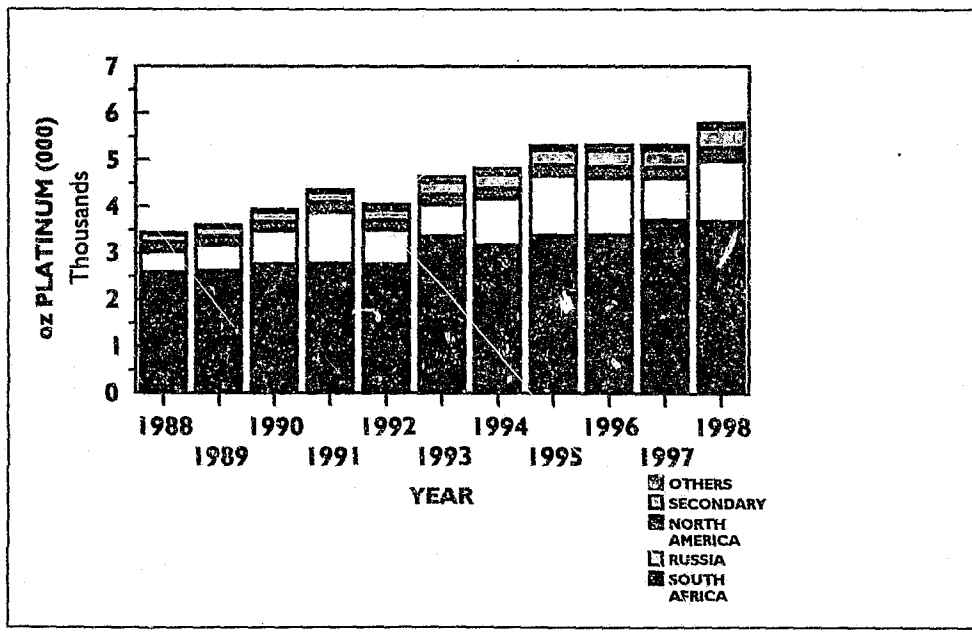


Figure 8.6 Increase in world supply 1988 to 1998

From the above, the following can be summized:

- Present levels of world platinum supply are dependent on South African production.
- Levels of platinum supply from South Africa's main competitor, Russia, are highly erratic.
- Only 14% of platinum is currently supplied from countries outside of Russia and South Africa.
- Known world platinum resources are currently depleted at an approximate rate of 0.38% per annum.

8.3 Future Supply (Forecast of Production for 1999 and Beyond)

8.3.1 South Africa

Expected expansions to platinum production in South Africa are detailed below. A total increase in supply of 183 000 oz is estimated. This will increase total South African supply from 3 777 000 oz in 1998 to 3 960 000 oz in 1999. The author estimates a further increase in South African supply of 185 000 oz in 2000.

Amplats. An upgrade of concentrator facilities at Potgietersrus Platinum Mine is expected to increase milling capacity by 70%. This should result in the production of an additional 50 000 oz of platinum per annum, from 1999.

The new Bafokeng-Rasimone Mine will begin stoping operations in 1999, and plans to produce the first concentrate in January 2000. The mine is expected reach a milling rate of 200 000 t by April 2000 and is planning to produce an annual supply of 250 000 oz of platinum by 2002.
Lebowa Platinum Mine, in the Eastern Limb, will expand operations through the upgrading of hoisting capacity at its main shaft and the

exploitation of a small UG2 deposit at Middelpunt Hill. These expansions are expected to yield an additional 21 000 oz of platinum per annum by 2001.

The concentrator at Amandelbult Mine, in the Western Limb is being upgraded to mill an additional 60 000 t of UG2 per month. This should result in additional 72 000 oz of platinum per annum by the final quarter of 2000.

Although there are a number of expansions taking place in Amplats over the next few years, a lot of the additional platinum production will replace exploited reserves. It is expected that Amplats will increase their supply of platinum from 1 861 000 oz in 1998 to around 1 950 000 oz in 1999. The author expects this supply to increase to 2 000 000 oz per annum in 2000. Johnson Matthey (1999) predict that the total Amplats production of platinum will be "lifted to around 2.25 Moz over the next three or four years".

Implats. A major capital investment programme is underway to extend and establish declines to access deeper reserves from existing infrastructure at the Impala Mines. This expansion is aimed at accessing high grade Merensky Reef and replacing exploited reserves. Although mill throughput at the mines is expected to remain at 14.5 Mt per annum, it is expected to improve in grade and thus increase platinum production to around 1 100 000 oz per annum by 1999.

The reopening of Barplats' mothballed Crocodile River Mine is being investigated and a detailed feasibility study is expected by the end of 1999.

The Everest Project in the Eastern Limb of the BC, is being investigated as a potential future source of UG2.

It is expected that Implats will increase their supply of platinum from 1 059 000 oz to around 1 100 000 oz per annum in 1999 (Mc Mahon, 1998). The author expects this supply to remain around these levels in 2000.

Lonplats. An expansion involving the upgrade of smelter and concentrator facilities at the Lonplats mines is expected to increase platinum production to around 700 000 oz per annum by the year 2001 (Wilkinson, 1998).

Lonplats will increase supply of platinum from 627 000 oz per annum in 1998 to around 640 000 oz per annum in 1999. The author expects this supply to increase further to 650 000 oz in 2000 and 700 000 in 2001.

Northam Platinum Mine. Modifications and additions to the smelter feed system are expected to allow Northam a mill throughput of 150 000 t per month. This should allow for a total annual throughput of 1.8 Mt for 1999. As a result Northam is expected to increase platinum production from 200 000 oz to around 210 000 oz per annum for 1999. This output is expected to be maintained for 2000 and 2001.

Aquarius. The Kroondal Platinum Mine, in the Western Limb of the BC is expected to commence with operations in April 1999. It is expected to reach its target production of 100 000 oz of platinum per annum by January 2000. It is estimated that the mine will account for some 30 000 oz of platinum, via toll smelting and refining at Implats, in 1999 (Adams, 1998). Feasibility work will continue on its Marikana Project with production from this resource potentially coming on line in 2001 (Adams, 1998). Aquarius will ultimately be responsible for about 3% of South African platinum production. The Kroondal Mine will have an annual output of 1.2 Mt of ore, producing a 350-1000 g/t concentrate (Forrest, 1998). This will be refined to precious metal products by Implats.

Messina Platinum Mine. Situated in the eastern Limb of the BC is likely to be acquired by Southern Era in the second half of 1999. The current owners, Implats, mothballed the mine in 1990. The mine is based on a resource of 51 Mt at a grade of 6.4 g/t 3PGM+Au (or 10.48 Moz PGM+Au). The resources include a strike length of 16 km of UG2 and Merensky reef. Both reefs dip at 58° and are 120 m apart. The mine plans to produce 120 000 oz of PGM+Au annually, from 2001 (Crankshaw, 1999).

Platexco. Plans to begin production from its Winnaarshoek Platinum Group Metals Project in the Eastern Limb of the BC, in 2000. The mine has a resource of 80 Mt at an average grade of 6.65 g/t 3-PGM+Au (Brink, 1999). Production is estimated at 600 000 oz of PGM+Au annually.

8.3.2 Russia

Russian producers are expected to increase production of platinum to around 850 000 oz per annum in 1999 (550 000 oz from Norilsk and 300 000 oz from alluvial workings). Most market analysts, however, estimate that stocks of platinum controlled by Almaz (see chapter 5) are at an end. Supply in 1999 and 2000 is thus likely to be equal to or closely approximate production from mining operations. The author estimates a supply of 900 000 oz per annum of platinum for 1999 and 2000. This will be 400 000 oz less than the 1 300 000 supplied in 1998.

8.3.3 North America

Expected expansions to platinum production from North American producers are detailed below. A total drop in platinum supply of 48 700 oz is estimated. This will see a decrease in North American supply from 292 700 oz in 1998 to 244 000 oz in 1999. The author estimates that about 340 000 oz will be produced in 2000.

Stillwater Mining Company, is busy with a "substantial expansion project", which aims to triple production by 2001 (Johnson Matthey, 1999). It plans to accomplish this by increasing production at its Nye Mine and initiating production from the new East Boulder prospect. Johnson Matthey (1999), however, suggest that a poor nickel market is likely to cause a 6% drop in PGM output for 1999 to 206 000 oz (or 50 000 oz platinum). Additional production from expansion in 2000 should see platinum output increase by about 150 000 oz in 1999.

Falconbridge, is expected to contribute more by-product PGM in 1999 as the new Raglan Mine produces for the first time (Johnson Matthey, 1999). This additional production should increase annual platinum output from 30 000 oz in 1998 to 40 000 oz in 1999 (Falconbridge, 1999). The author expects these levels to be maintained in 2000.

Inco, is expected to rationalise in an effort to reduce costs of nickel production (Johnson Matthey, 1999). Production of platinum is, however, expected to remain at current levels for 1999 and 2000.

North American Palladium, will be affected by the processing of lower grade ore in 1999 and is expected to drop platinum production by 18%. This will see a platinum output of 4 000 oz for 1999 and possibly 2000.

8.3.4 Zimbabwe

The closure of Hartley Platinum Mine, Zimbabwe's biggest producer to date, has resulted in a significant drop in production of platinum, from some 135 000 oz in 1998 to an estimated 50 000 oz in 1999. Increases in supply are, however, likely to be seen as a result of expansions and projects within Zimplats and Anglo American Zimbabwe, the countries two largest producers. A total decrease in supply of 80 000 oz is estimated

for 1999, and 60 000 oz for 2000. Production is expected to increase to 500 000 oz by 2006/7 (Nutt, 1999).

Zimplats. Zimplats is involved in joint ventures with BHP in Hartley Platinum Mine and the undeveloped Mhondoro project. In addition, it is the sole owner of the Ngezi prospect which plans to produce 3 Mt of ore per annum (Johnson Matthey, 1999) and the Mimosa Mine which currently produces 330 000 t of ore per annum. The feasibility study for underground and open cast operations at Ngezi is expected to be completed at end 1999. Mimosa Mine is expected to retain an output of 25 000 oz over the next two to three years.

Anglo American Zimbabwe. Anglo American Zimbabwe plans to bring a new platinum mine at Unki into production within the next two to three years. The planned production rate is 118 000 oz per annum.

8.3.5 Other

Although there is a significant drive in exploration for platinum bearing deposits and ores, there is to date very little promisel of any "other" deposits yielding any significant supply over the foreseeable future. It is estimated that there will be no additional platinum supply from "other" sources over the next two years.

8.3.6 Secondary supply

Secondary supply, as mentioned above, is derived predominantly from the recycling of auto-catalytic convertors. This supply is directly related to the increasing demands of emissions control legislation (explained in greater detail in chapter 4). The load of PGM's required to ensure that emissions standards are met, is likely to increase significantly over the next few years. In addition legislation to be imposed by the European Union, is likely to enforce a far larger commitment to recycling in Europe. The author estimates the secondary supply of platinum to increase by a minimum of 35 000 oz in 1999, and by a further 50 000 oz in 2000.

Table 8.13 Estimated increase or drop (-) in world platinum supply year on year

PROJECT / MINE (Company)	DEPOSIT	OUNCES OF PLATINUM (000) 1999	OUNCES OF PLATINUM (000) 2000
Winnarshoek (Platexco)	Bushveld Complex, Eastern limb	0	30
Messina Platinum Mine (Southern Era)	Bushveld Complex, Northern Limb	0	0
Marikana Project (Aquarius)	Bushveld Complex, Western limb	30	100
Stillwater Mines (Stillwater Mining Company)	Stillwater Complex	-58	92
Amplats Expansions	Bushveld Complex, Western Limb	89	139
Implats Expansions	Bushveld Complex, Western Limb	41	41
Lonplats Expansions	Bushveld Complex, Western Limb	13	23
Crocodile River	Bushveld Complex, Western Limb	0	25
Northam	Bushveld Complex, Western Limb	10	10
Russian Supply	Norilsk Talnakh	-400	-400
Zimbabwean Supply	Great Dyke	-80	-60
Secondary Supply	Spent autocatalysts	35	50
TOTAL		**-320**	**50**

8.4 Summary

World Supply of platinum is an estimate of the quantity of platinum made available to markets annually. Platinum is supplied from production, recycling and stockpiles. Production of "new" metal accounts for the greatest proportion (about 85%, currently) of annual supply. An accurate estimation of annual production is thus critical to a "supply and demand balance". Figures used in this report have been sourced from reports of

Market Analysts, Annual Reports of Producers and authors. A more accurate method of measurement of production is discussed in chapter 10 (Summary).

Research used for the estimation of world platinum supply indicates the following:

- World resources are estimated to amount to 1.564 Moz of platinum.
- South Africa contains 68% of these resources and is the worlds largest platinum producer and supplier (about 3.777 Moz in 1998).
- Russia contains 8% of the worlds platinum resources in nickel dominated deposits. It currently produces about 700 000 oz annually and supplies about 1.3 Moz.
- The US, Canada, Zimbabwe and Secondary Supply make up the remainder of current world supply.
- The world is currently supplied with 5.915 Moz of platinum per annum.
- A drop in supply of 320 000 oz is expected in 1999. This is mainly due to lack of supply from Russian stockpiles and lack of production from the Great Dyke.
- Western world producers are expected to expand rapidly in an attempt to make up a predicted shortfall in 1999 and 2000. As a result platinum supply in 2000 is expected to recover to a similar quantity as that supplied in 1998 (about 5.915 Moz).

9 WORLD PLATINUM DEMAND

This chapter provides an estimate of current and future world demand for platinum. The estimate is based on "intensity of use" derived figures for demand by application and region. Most of these demand figures are sourced from annual reports of Johnson Matthey who have proved over time to be a reliable source of statistics for the platinum market. Chapters three, four and five have explained how demand for platinum is driven by specific uses (resulting from its properties), requirements of legislation and innovative marketing practices. A prediction of future demand is made by evaluating the potential effect that these "driving" forces are likely to have.

9.1 The Platinum Product

Platinum is demanded by consumers for various applications in specific forms. The commodity is supplied by fabricators as a pure metal or a compound depending on requirements. Refined platinum is commonly made available to the market in the form of ingots with a purity of 99,95%. Ingots, characteristically greater than 10 oz are traded at spot metal prices on world markets and exchanges. These include the Tokyo Commodity Exchange (TOCOM), the London Platinum and Palladium Exchange and the New York Mercantile Exchange (NYMEX). Platinum is most commonly traded in dollars ($) per ounce (oz).

9.2 Current Demand for Platinum by Application

Most uses for platinum are described in greater detail in preceding chapters (3, 4 and 5). Figure 9.1 illustrates the proportionate amount of platinum used in these various applications (for 1998). Current estimated demand for platinum is discussed, by application below.

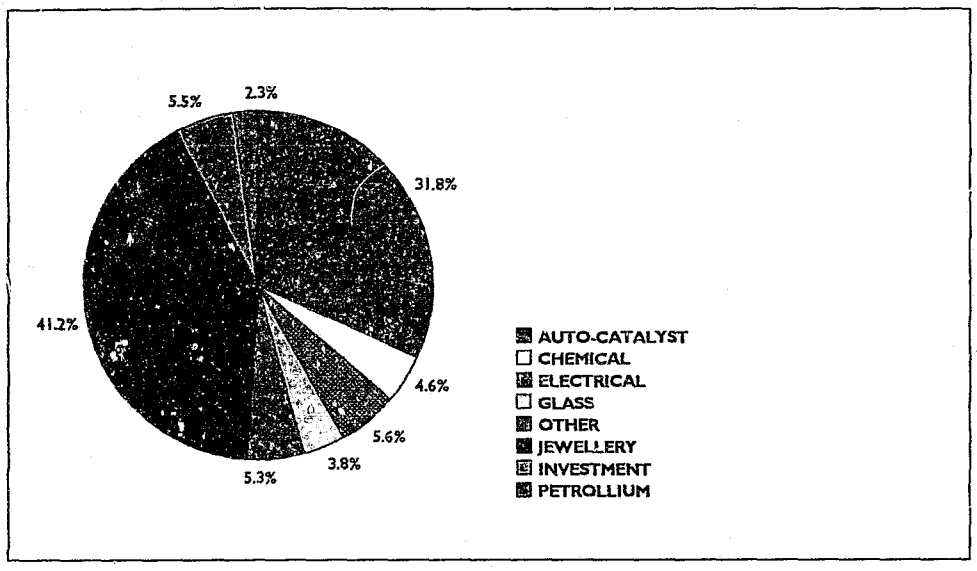


Figure 9.1 Share of platinum demanded by applications (1998)

9.2.1 Autocatalysts

Estimated annual platinum demand for use in autocatalysts in 1998 was 1.83 Moz (Johnson Matthey, 1999). Although this is a decline on the high of 1.88 Moz in 1996, it is largely related to a cheaper palladium price and the switch by automanufacturers to palladium-rich catalysts for petrol driven vehicles. Johnson Matthey (1999) report that this loss in demand was partially offset by higher platinum loadings required by legislation for diesel catalysts.

Demand for platinum in Europe rose by 25 000 oz (to 535 000 oz) as a result of a 7% increase in vehicle sales. This increase was largely the result of a growing consumer preference for diesel powered vehicles. Johnson Matthey (1999) report an 18% increase in sales of diesel vehicles resulting from improved engine performance, low fuel consumption and substantially lower taxes imposed by EU countries. All vehicles sold in Europe since 1997 have had to carry platinum autocatalysts to comply with Stage II EU emissions limits.

Platinum sales to Japanese manufacturers fell by 15 000 oz to 240 000 oz in 1998. This resulted from a slump of 5% in total vehicle production, a fall

in personal incomes, low consumer confidence and a poor economy in 1998. Most autocatalysts in Japan, however, contain high platinum loadings (Johnson Matthey, 1999).

Increased vehicle sales (up 3%), good economic growth and high consumer confidence in 1998, accounted for a 10 000 oz increase in autocatalyst demand for platinum in North America. Although automanufacturers switched to palladium rich catalysts to meet NLEV standards, platinum in light trucks increased and there was a build up in consumer inventories.

Generally poor economic conditions depressed vehicle sales in South America and Asia. This outweighed the increase in autocatalysts fitted and resulted in a 20 000 oz drop in platinum demand for the "rest of the world" (Johnson Matthey, 1999).

Table 9.1 below gives a regional breakdown in estimated demand for platinum in autcatalysts, for 1997 and 1998. It is interesting to note the increased demand in Europe. Substitution by palladium and reduced world car sales account for the current, stable demand for platinum in this sector.

Table 9.1 Annual demand for platinum in production of autocatalysts for 1997 and 1998, by region (sourced from Johnson Matthey, 1999)

REGION	DEMAND FOR PLATINUM IN 1997 (000 oz)	DEMAND FOR PLATINUM IN 1998 (000 oz)
EUROPE	510	535
JAPAN	255	240
NORTH AMERICA	800	810
REST OF THE WORLD	265	245
TOTAL	**1,830**	**1,830**

9.2.2 Jewelry

World demand for platinum in jewelry grew by 210 000 oz to 2.37 Moz in 1998 (Johnson Matthey, 1999). This was the result of a significant expansion in Chinese and US markets. The expansion more than offset reduced sales in Japan.

A poor Japanese economy, credit restrictions imposed by banks and the increase in sales tax, saw sales of platinum metal and finished jewelry, fall in Japan in 1998. Although this economic downturn affected platinum, it had a far greater effect on other precious metals (particularly gold). Platinum was, therefore, able to gain a larger share of the market. During 1998 a number of low profit manufacturers and distributors were forced out of the market due to bankruptcies and the withdrawal of credit from banks (Johnson Matthey, 1999). This allowed for greater monopolies for larger more profitable producers in Japan.

Demand for platinum jewelry in China (currently the fastest growing market for the metal) surged to 620 000 oz in 1998, from 360 000 oz in 1997. This growth was the result of clever marketing practices of PGI and the "vigorous expansion in the fabrication of inexpensive platinum pieces" (Johnson Matthey, 1998).

Demand for platinum jewelry in Europe grew by only 5 000 oz to 155 000 oz for 1998. A decline in economic growth in Germany affected domestic sales while, in contrast, Italy's export market improved. The latter increasing sales of light-weight platinum chain to the US and China. Good marketing practices improved "bridal sector" sales in the UK, while Swiss watch sales decreased (Johnson Matthey, 1999).

Demand for jewelry increased in North America by 60 000 oz to 220 000 oz in 1998. This was primarily the result of increased exposure of bridal products in retail outlets. Courage (1998) reports that the US, PGI marketing programme is focused on the expanding market for wedding and engagement rings.

The "rest of the world" was predominantly affected by lower exports to Japan and fell by 15 000 oz to 85 000 oz in 1998.

Table 9.2 shows the estimated demand for platinum jewelry by region, for 1997 and 1998. It is interesting to note the effect of PGI marketing strategies in increasing platinum jewelry demand in China and North America.

Table 9.2 Annual demand for platinum in jewelry for 1997 and 1998, by region (sourced from Johnson Matthey, 1999)

REGION	DEMAND FOR PLATINUM IN 1997 (000 oz)	DEMAND FOR PLATINUM IN 1998 (000 oz)
JAPAN	1,390	1,290
CHINA	360	620
EUROPE	150	155
NORTH AMERICA	160	220
REST OF THE WORLD	100	85
TOTAL	**2,160**	**2,370**

9.2.3 Chemical uses

Demand for platinum in the chemical industry rose by 30 000 oz to 265 000 oz in 1998 (Johnson Matthey, 1999). This resulted from increased production of benzene in the Middle East, silicones in North America and Europe and nitric acid (for use in explosives and fertilizers) in the US and Europe. Demand was offset by lower investment in some "bulk chemical processes" due to the Asian economic crisis (Johnson Matthey, 1999). Table 9.3, below, illustrates the growth in demand resulting from benzene production in the "rest of the world" sector.

Table 9.3 Annual demand for platinum in chemical manufacture for 1997 and 1998, by region (sourced from Johnson Matthey, 1999)

REGION	DEMAND FOR PLATINUM IN 1997 (000 oz)	DEMAND FOR PLATINUM IN 1998 (000 oz)
EUROPE	70	60
JAPAN	20	20
NORTH AMERICA	80	80
REST OF THE WORLD	65	105
TOTAL	**235**	**265**

9.2.4 Electrical uses

Platinum demand in the electronics industry grew by 15 000 oz to 320 000 oz in 1998 (Johnson Matthey, 1999). This growth was mainly the result of increased demand for platinum bearing hard discs in personal computers (PC's). Due to the economic crisis in Asia there was a decline in world steel and semiconductor manufacturing. This resulted in a lower demand for platinum bearing thermocouples which are used in the manufacture of these products. Johnson Matthey (1999) report on a small, but growing demand for platinum in fuel cells. There are currently only a small number of fuel cell powered vehicles, but most manufacturers have designed demonstration cars and a small fleet of prototype busses exists in North America. As these vehicles are dependent on larger quantities of platinum (when compared to petrol powered vehicles), the "large scale" manufacture of fuel cells is reliant on favourable platinum prices. Johnson Matthey (1999) report on the use of a proton exchange membrane (PEM), used in fuel cell vehicles, for stationary power generation. Small 2 and 50 kilowatt units are targeted at homes and businesses in remote areas. A number of these units are being demonstrated in the US and Europe. Table 9.4, below, shows the estimated demand for platinum in electronics

by region, for 1997 and 1998. The "rest of the world" and North America show increases in demand due, mainly, to increased manufacture of PC hard discs.

Table 9.4 Annual demand for platinum in the electronics industry for 1997 and 1998, by region (sourced from Johnson Matthey, 1999)

REGION	DEMAND FOR PLATINUM IN 1997 (000 oz)	DEMAND FOR PLATINUM IN 1998 (000 oz)
EUROPE	25	45
JAPAN	50	65
NORTH AMERICA	150	105
REST OF THE WORLD	80	105
TOTAL	**305**	**320**

9.2.5 Glass

Platinum demand in glass manufacture, fell from 45 000 oz to 220 000 oz in 1998 (Johnson Matthey, 1999). This was primarily due to the Asian crisis, with 90% of the worlds LCD glass manufacture being concentrated in the Far East. Johnson Matthey (1999) report that expansions in LCD manufacture in Taiwan and Korea, contributed to excess capacity and an over-supply of units. This resulted in a sharp decline in LCD prices in 1999 and reduced investment in further expansion. Growth in the glass fibre industry, contributed to an increased demand for platinum. Most expansion in glass fibre production was in China, where there is expansion in the economy, despite the Asian crisis elsewhere. Table 9.5, below, shows estimated world platinum demand for glass manufacture by region, in 1997 and 1998. Poor consumption, for this application, in Japan, North America and the "rest of the world" is illustrated.

Table 9.5 Annual demand for platinum in glass manufacture for 1997 and 1998, by region (sourced from Johnson Matthey, 1999)

REGION	DEMAND FOR PLATINUM IN 1997 (000 oz)	DEMAND FOR PLATINUM IN 1998 (000 oz)
EUROPE	20	25
JAPAN	85	80
NORTH AMERICA	45	20
REST OF THE WORLD	115	95
TOTAL	**275**	**220**

9.2.6 Investment

Demand for platinum investment products grew by 75 000 oz to 315 000 oz in 1998 (Johnson Matthey, 1999). This increase was mainly due to the success of the American Eagle bullion and proof coins. Sales in the Eagle increased by 50% to 175 000 oz in 1998. An increase in small coin (ie. coins weighing one tenth or one quarter of an oz) sales for use in jewelry also contributed to the success of the investment sector. Investment in large bars is largely dependent on the yen price of platinum and the state of the Japanese economy. Sales in these bars surged in the last quarter of 1998 due to low platinum prices. Accumulation plans (discussed in chapter 5) also contributed to a 40 000 oz increase in demand for large bars in 1998. Table 9.6 shows the estimated world demand for platinum investment products by region, in 1997 and 1998.

Table 9.6 Annual demand for platinum as a means of investment for 1997 and 1998, by region (sourced from Johnson Matthey, 1999)

REGION	DEMAND FOR PLATINUM IN 1997 (000 oz)	DEMAND FOR PLATINUM IN 1998 (000 oz)
EUROPE	5	5
JAPAN (incl. Large and small bars*)	85	130
NORTH AMERICA	145	175
REST OF THE WORLD	5	5
TOTAL	**240**	**315**

9.2.7 Petroleum

Demand for platinum in petroleum refining dropped by 40 000 oz to 130 000 oz in 1998 (Johnson Matthey, 1999). This was mainly due to weak economic conditions and a postponement of new refinery projects. Wider use of autocatalysts and increased vehicle sales in the "rest of the world" region, have contributed to platinum's use as a reforming catalyst in recent years. This demand contracted sharply in 1998, as weak economic conditions caused a downturn in investment and the postponement of new reformer construction in Chile and Malaysia. The dearomatisation of diesel fuels, required by legislation in Europe and North America resulted in demand remaining steady in these regions (Johnson Matthey, 1999). Table 9.7, below shows the estimated world demand for platinum in petroleum refining by region, for 1997 and 1998.

Table 9.7 Annual demand for platinum in petroleum refining for 1997 and 1998, by region (sourced from Johnson Matthey, 1999)

REGION	DEMAND FOR PLATINUM IN 1997 (000 oz)	DEMAND FOR PLATINUM IN 1998 (000 oz)
EUROPE	15	15
JAPAN	5	5
NORTH AMERICA	50	45
REST OF THE WORLD	100	65
TOTAL	**170**	**130**

9.2.8 Other uses

Demand for platinum in "other uses" increased by 10 000 oz to 305 000 oz in 1998 (Johnson Matthey, 1999). This was the result of increased platinum use in biomedical applications (treatment of cancer and angioplasty) and the aerospace industry (coating of turbine blades). There was a slight decline in the quantity of platinum required for oxygen sensors in on-board diagnostic systems. Demand for platinum in oxygen sensors also dropped as a result of lower world vehicle sales. This drop in demand was offset by increased use of platinum tipped spark plugs. Spark plugs were fitted to over 85% of vehicles produced in the North American region (Johnson Matthey, 1999). Table 9.8 shows the estimated world demand for platinum in "other uses" by region, for 1997 and 1998.

Table 9.8 Annual demand for platinum in other uses for 1997 and 1998, by region (sourced from Johnson Matthey, 1999)

REGION	DEMAND FOR PLATINUM IN 1997 (000 oz)	DEMAND FOR PLATINUM IN 1998 (000 oz)
EUROPE	85	85
JAPAN	30	30
NORTH AMERICA	160	170
REST OF THE WORLD	20	20
TOTAL	**295**	**305**

The total demand for platinum by application for 1997 and 1998 is shown in table 9.9 below. Even with a generally poor world economy over 1998 and increased substitution of platinum by palladium in autocatalysts, there was a 255 000 oz increase in estimated demand. Continued drive, by PGI in jewelry marketing, and by legislation in the use of catalysts is largely responsible for maintained growth in demand. New uses for platinum will continue to drive future demand for the metal.

Table 9.9 Total demand for platinum by applications in 1997 and 1998 (sourced from Johnson Matthey, 1999)

APPLICATIONS	DEMAND FOR PLATINUM IN 1997 (000 oz)	DEMAND FOR PLATINUM IN 1998 (000 oz)
AUTOCATALYSTS	1,830	1,830
JEWELRY	2,160	2,370
CHEMICAL	235	265
ELECTRICAL	305	320
GLASS	265	220
PETROLEUM	170	130
INVESTMENT	240	315
OTHER	295	305
TOTAL	**5,500**	**5,755**

9.3 Current Platinum Consuption (Demand) by Region

Increase in demand by region (1988 to 1998) is illustrated in figure 9.2. Table 9.10, below, illustrates changes in estimated platinum demand by region, in 1997 and 1998. Platinum derived from spent autocatalysts is included in these estimations. It is interesting to note the significant growth in demand in the rest of the world, North America and Europe. This growth is the result of stricter emissions legislation and increased intensity of jewelry marketing. A drop in Japanese platinum demand is a consequence of the Asian crisis. A significant decline in industrial use of platinum in the rest of the world was offset by vastly increased Chinese jewelry sales (a contribution of 620 000 oz).

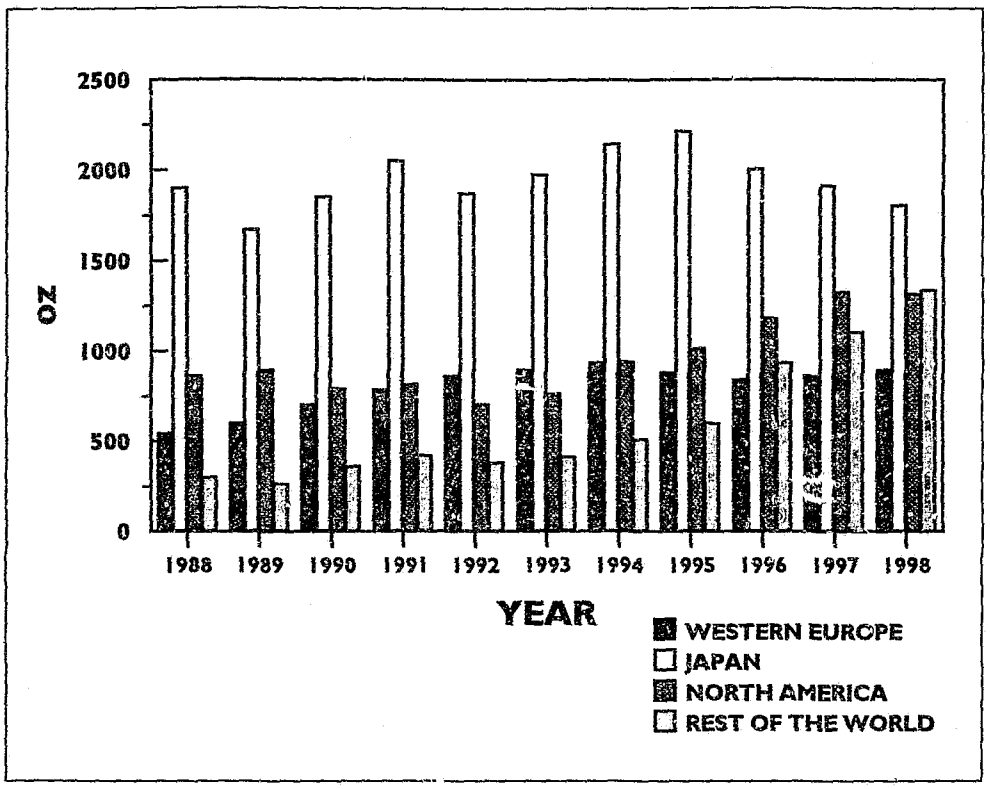


Figure 9.2 Growth in platinum demand 1988 to 1998

Table 9.10 Total annual demand for platinum by region, in 1997 and 1998 (sourced from Johnson Matthey, 1999)

REGION	DEMAND FOR PLATINUM IN 1997 (000 oz)	DEMAND FOR PLATINUM IN 1998 (000 oz)
EUROPE	875	895
JAPAN	1,885	1,805
NORTH AMERICA	1,250	1,315
REST OF THE WORLD	1,120	1,335
TOTAL	**5,130***	**5,350***

*These totals are reduced by secondary platinum supply

9.4 Estimated Future Platinum Demand

The principle factors that are likely to drive demand for platinum over the next few years are:

- Platinum price
- Legislation
- Jewelry marketing
- The state of the economy in consuming regions
- New uses and development of new technology involving platinum (particularly fuel cells).

The affect that these factors are likely to have on future platinum demand is discussed below.

9.4.1 Platinum price

The cost of platinum has a significant effect on consumption. Demand in the investment sector is directly related to the price of platinum. The lower the price the greater the consumption of platinum investment products. Jewelry consumption is also adversly affected by high prices, but this is offset by the steady bridal market, new marketing strategies and growth in new markets. Manufacturers who use platinum in industrial applications, usually rely on inventories to "see off high prices" and hedge against prices by entering into long, and medium term contracts with suppliers. Platinum price is expected to increase over the next two years discouraging the consumption of platinum in investment products.

9.4.2 Legislation

Stricter required emissions standards imposed by Developed countries (particularly in Europe, Japan and North America) is likely to force continued growth in platinum demand. The production of autocatalysts for diesel powered vehicles, OBD's and petroleum refining (in compliance

with legislation) are likely to have the largest affect on demand over the next two years. A sufficient increase in palladium price may cause automanufacturers to revert to platinum-rich autocatalysts, for petrol powered vehicles. The year 2000 is being used by most countries as a "model year" for imposing stricter legislation. The author expects legislation to continue to drive demand for platinum worldwide.

9.4.3 Jewelry marketing

Marketing of jewlery by PGI has been incredibly successful in new markets over the last few years. The aggressive strategies employed and the large number of new markets being tapped, are likely to induce increased growth in platinum demand in this sector. Growth in jewelry is directly related to the marketing drive by PGI. Being the marketing "arm" of Amplats they may well control activities to suit expected limited supply. The expected shortage in supply is therefore likely to slow growth in the jewelry market to some degree. The PGI campaign will, however, continue to create world awareness for the metal and endeavour to gain a greater share of the precious metal market.

9.4.4 Economies

A downturn in world economies is usually closely related to a curb in consumer spending and a reduced level of available credit. Countries going through an economic crisis are therefore likely reduce platinum consumption. This is illustrated by the drop in demand for platinum in Japan during 1997 and 1998. Most platinum consuming countries are expected to have improving economies over the next two years, stimulating the consumption of platinum.

9.4.5 New uses and technology involving platinum

There is continual reliance on the unique properties of platinum. This is evident in virtually all industries which make use of the metal. Platinum has survived supply shortages and high prices, without substitution and significant thrifting. This is testimony to the fact that it is currently irreplaceable in most of these applications. New products and technology being discovered are making more and more use of the properties of platinum. Examples of this are most evident in computer and automotive industries, where hard discs and fuel cells are currently being developed and tested. These and other, yet undiscovered uses for platinum are likely to further drive demand for the metal over the next two years.

The author expects a continued steady increase in world demand of about 250 000 oz in 1999. Strong growth is likely to result from increased use in autocatalyst, jewelry and chemical applications. A decline in platinum as an investment vehicle and stable petroleum, glass and "other" industries are likely to offset this growth.

A more significant drive in demand can be expected in 2000. This is likely to be caused by the initiation of tighter emissions control legislation in a number of countries, in *this* year. The author believes that expected supply shortages will drive prices up and moderate this demand, to some degree.

9.5 Summary

Estimated world demand (based on Johnson Matthey, 1999 figures) shows a steady increase between, 1997 and 1998, of 255 000 oz. This has occurred in spite of platinum substitution by palladium in autocatalysts and a weak Asian economy over this period. Aggressive marketing of platinum in jewelry, new uses reliant on platinum properties and stricter legislation are seen as driving forces for future demand. An

improved world economy is likely to further increase demand. If palladium prices increase sufficiently, automanufacturers will be forced to revert to greater use of platinum in autocatalysts. This, in addition to increased standards imposed through legislation (on petrol and diesel emissions, on-board monitoring and cleaner fuels), is likely to significantly drive demand. The only technology currently available to replace the use of autocatalysts is the fuel cell. This power source, currently being developed and tested, requires greater consumption of platinum per vehicle than the autocatalyst. The author believes that there are a sufficient number of good reasons to suggest a strong drive in demand over the next few years. This may be offset, in part by a drop in supply.

10 BALANCE OF SUPPLY AND DEMAND

The previous two chapters have provided estimates of world supply and demand for platinum. This chapter reviews these figures and provides a current and future balance for the market. The relevance of this balance is also discussed. The two data-sets used for supply and demand totals, together with the derived and predicted balances for 1998, 1999 and 2000 are tabulated below (Table 10.1).

10.1 Current World Supply and Demand Estimates

The total, current, world supply of platinum is derived by estimating annual production, recovery from scrap and depletion of Russian stockpiles. Production is reliant on resources which are sparse and concentrated in South Africa, Russia, Zimbabwe, the USA and Canada. South Africa has some 64% of world resources in the Bushveld Complex. Current world supply is thus dominated by South African production, with 3.78 Moz being produced in 1998. In addition, 0.7 Moz were produced in Russia, 0.29 Moz in North America and 0.13 Moz in Zimbabwe. A further 0.4 Moz were supplied from scrap recovery and 0.6 Moz from Russian stocks. The total current (1998) supply estimate amounted to 5.915 Moz.

The total, current, world demand for platinum is derived by estimating its intensity of use in various applications. Jewelry and autocatalyst production consume the most platinum, 73% of total demand. Japan leads current world demand by region, with 1.805 Moz. Total world demand is estimated at 5.755 for 1998. A breakdown by application is provided in the previous chapter (Table 9.9).

10.2 Future Total Supply and Demand Predictions

A forecast of future platinum supply and demand is dependent both on current trends and future predictions. A prediction of future demand is made by investigating the following:

- The potential growth in industries using platinum.
- The planned demand for the manufacture of new products containing platinum.
- The potential requirements of legislation (increased loadings to meet stricter emissions standards).
- The drive of jewelry marketing.
- The willingness of consumers to purchase platinum.
- The investment potential for platinum.

Future supply predictions are made by investigating expansions to existing production, potential for new production, constraints on production, supply available in Russian stockpiles and the potential contribution from secondary supply. The current trends of supply and demand will enhance the forecast.

A decrease in total annual supply over the last few years, suggests production constraints and stockpile shortages. The "start up cost" inhibits a closed operation from immediately reacting to a price high. Depleted stocks are only replenished at the expense of production supply. This decreasing supply trend suggests a period of shortage in platinum availability, which can only be corrected after a production "start up" period. A forecast based on the existing demand trend, is similar. A strong, growing consumption of platinum jewelry, for example, is not likely to collapse overnight. In addition, substitution and thrifting are only possible after a period of time. Development and testing must be completed before the use of one metal can be substituted for by another.

This study forecasts a continued decrease in world platinum supply. This is predominantly due to the depletion of Russian stockpiles and the

reduced production from Zimbabwean mines. South African producers will attempt to make up the shortfall, but expansion to existing operations can only be expected after a start up period of about two to three years. World supply is forecast to drop by 320 000 oz in 1999. A similar quantity supplied is expected for 2000.

Future world demand for platinum is expected to continue its steady growth. Stricter legislation on emissions, and increased use of autocatalysts, should result in good growth in consumption in the automotive industry. The marketing campaign of PGI should continue to create awareness and desire for platinum jewelry, although Amplats may choose to be less aggressive in lieu of supply shortfalls. Development and testing of new uses for platinum is expected to continue. Fuel cells, in particular are expected to account for an ever increasing demand. This study suggests a 250 000 oz increase in world platinum demand per annum over the next two years (1999 and 2000).

10.3 Deriving a Supply and Demand Balance

A predicted balance, comparing future supply and demand is most useful in market forecasts. The greater the accuracy of such a balance, the greater the confidence an analyst will have in understanding the state of the market. A predicted balance calculation allows an analyst to satisfy questions such as whether future supply will be capable of responding to future demand. It will indicate whether there is an excess in supply of platinum, or a shortfall of platinum required. The latter would be made up by depletion of inventories and the former would provide inventory addition. Table 10.1, below, provides a supply and demand balance for platinum in 1998 and a predicted balance for 1999 and 2000. It must be stressed that such predicted shortfalls or excesses merely provide an indication of the state of the market. The strength of this indication is dependent on the accuracy of the "input" figures for supply and demand.

Table 10.1 Estimated supply and demand balance for platinum in 1998, 1999 and 2000 (000 oz)

SUPPLY				
1. PRODUCTION				
REGION	**OPERATIONS**	**1998**	**1999**	**2000**
SOUTH AFRICA	Amplats, Implats, Lonplats, Northam,	3777	3960	4145
RUSSIA	Norilsk	700	850	850
NORTH AMERICA	Stillwater, Inco, North American Palladium,	293	235	385
ZIMBABWE	Hartley BHP, Mimosa	135	55	75
OTHERS	Jinchuang, Outocumpo	5	5	5
SUBTOTAL		**4910**	**5105**	**5460**
2. SECONDARY SUPPLY				
RECYCLING OF AUTOCATALYSTS		405	440	490
3. ADDITIONAL				
RUSSIAN STOCKPILE DEPLETION		600	50	50
TOTAL		**5915**	**5595**	**6000**
DEMAND				
APPLICATION		**1998**	**1999**	**2000**
AUTOCATALYSTS		1830		
JEWELRY		2370		
CHEMICAL		265		
ELECTRICAL		320		
GLASS		220		
PETROLEUM		130		
INVESTMENT		315		
OTHER		305		
TOTAL		**5755**	**6005**	**6255**
BALANCE	(EXCESS: +, SHORTFALL: -)	**160**	**-410**	**-255**

10.4 Analysis of the Balance

A balance is the "end-product" of an understanding of all factors which affect the supply and demand of a commodity. It is the result of a thorough accounting of platinum produced, supplied, recycled and consumed. An excess or shortfall in supply provides a tool with which critical assessments of the market can be made. This study shows an excess of platinum supply for 1998 and a predicted shortfall for 1999 and 2000. The implications of these balances are discussed below.

10.4.1 Excess in 1998

Estimates suggest a small excess of 160 000 oz of platinum in 1998. This excess can be attributed to a significant "over-supply" of 1 300 000 oz from Russia (600 000 oz from stockpiles) and some substitution of palladium for platinum in autocatalysts. Although most consumers recognize this excess as "artificial" it appears to have had the following affects on the market:

- A building up of consumer inventories
- A steady, slightly suppressed price
- An increase in purchases of investment and jewelry products
- An increased drive in jewelry marketing (particularly in China)
- Increased use in new applications

10.4.2 Shortfalls in 1999 and 2000

Estimates suggest a shortfall of 410 000 oz of platinum in 1999 and 255 000 oz in 2000. These shortfalls are the result of significantly reduced supply and steady growth in demand. Supply is likely to be severely affected by a drop in production from the Great Dyke (the closure of Hartley Mine) and the lack of remaining Russian stockpiles. These constraints are predicted to account for a 500 000 oz loss of supply.

Although other producers are expanding operations, little of this loss is likely to be made up elsewhere over the next two years. Demand, however, is predicted to increase steadily by 250 000 oz. This will mainly be driven by new uses, jewelry marketing and increasingly stricter legislation. The predicted shortfalls are likely to trigger the following reactions:

- A depletion of inventories
- An increase in spot metal and contract prices
- A significant drive on production expansion projects
- A "let-off" in the aggressive marketing of PGI
- A drive towards substitution and thrifting, by consumers

Chapter 8 provides details of expansions to operations and new projects, currently initiated by producers. The main platinum primary product producers (Amplats, Implats, Lonplats and Stillwater) are rapidly increasing capacity to meet predicted shortfalls and satisfy consumers of a steady future supply. New projects in the Bushveld Complex, Stillwater Complex and Great Dyke are being urgently pursued. The author believes that the vast majority of these projects and expansions have commenced too late to benefit from the predicted high prices in 1999 and 2000. Kroondal Platinum Mine is one of the few projects that is likely to capitalize on predicted supply shortfalls. It will reach full production in 1999, allowing the controlling company, Aquarius, to benefit from high prices and maximise profits. The strategy adopted by this company, in timing the commencement of its project, can either be ascribed to chance, or well predicted insight into the state of the platinum market. Most new projects and expansions, however, are planned in reaction to high prices rather than prior predictions of high prices. Such strategies by producers are the result of conservative planning and the lack of confidence in predictions. It is the authors firm belief that accurate forecasts of supply excesses or shortfalls should be continually tested by producers and should play a far greater role in long term company strategies.

10.5 Prediction of Price

A supply shortfall will tend to drive platinum prices upward and an excess will drive prices downward. The magnitude of shortfall or excess determines the degree to which prices are likely to be driven. Moderating factors come into effect if a shortfall or excess persists. The current predicted world shortfall in platinum supply is likely to drive prices upward. Continued shortage in supply will encourage prices to continue in this direction. A long-term period of high prices, however, will tend to cause moderating factors to become effective.

Such predictions of price behavior based on the supply and demand balance are merely estimated indications. Although they give the market an idea of expected price trends, they should be complimented with a theoretical study of the platinum market behavior. This involves a study of the metals' price cycles, futures markets, forward contracts, and its relationship with other commodities. Davutyan and Roberts (1994), have proved that most metal commodities "can be described as having some degree of cyclicity, in the sense that there is a duration dependence on the length of phases" of high or low prices. This study is explained in more detail in the Appendix.

11 SUMMARY

Platinum trades in a unique precious metals market. As a commodity it is demanded both as an investment tool (or store of wealth) and a product essential in a number of industrial applications. This study examines the current world market for this commodity in terms of its supply and demand. A number of factors, critical to an understanding of supply and demand are dealt with in chapters 3, 4, 5, 6 and 7. These factors are summarized below. Estimated figures for current (1998) demand and supply are presented in chapters 8 and 9. The significance of these figures, in deriving a supply and demand balance is discussed in chapter 10 and summarized below. The implications of an excess or shortfall in world platinum supply affects both the producer and the consumer. These implications (discussed in chapter 10) are listed below.

11.1 Understanding the "Critical Factors" Affecting Supply and Demand

11.1.1 Unique properties

Platinum has a number of properties which make it highly sought after in certain industrial applications. Amongst others, it is highly resistant to oxidation and corrosion, has a very high melting point (1768°C) and is an ideal catalyst. Due to these properties it is estimated that one in every five goods manufactured either contains, or is produced using platinum. It is particularly prominent in the Automotive, Chemical, Electrical, Glass and Petroleum Industries. Its most important properties as a catalyst are in convertors for vehicles, petroleum refining and the manufacture of explosives and fertilizers. As a loading in certain autocatalysts it is currently irreplaceable. New uses for platinum are continuously being discovered. It is estimated that fuel cell technology, currently being

developed requires double the platinum content of a normal petrol powered vehicle. Fuel cell technology is expected to account for some 3 Moz (more than half of the current world production) in 2020. The properties of platinum therefore ensure a steady growth in its demand as a commodity.

11.1.2 Legislation

Emissions from the worlds 700 million vehicles is of growing concern to developed and developing countries. Harmful emissions include; hydrocarbons (HC), carbon monoxide (CO), nitrous oxide (NOx) and particulate matter (PM). Deaths related to vehicle pollutant emissions are estimated to be in the order of 80 000 per annum, in Europe alone. This has prompted governments to impose controls on emissions. Such controls are currently implemented as legislation in North America, Europe and Japan (76% of the worlds vehicle population). In order to comply with the required standards of emissions, automanufacturers are forced to improve the "cleaning" capabilities of their catalysts. These catalysts rely on the abilities of PGM loadings to convert the pollutant emissions to harmless H_2O, CO_2 and N_2. As standards of emissions become stricter there is an increased need for higher, more effective loadings. This translates to an ever increasing demand for platinum. Research shows that standards in North America, Europe and Japan, currently demand half of the emissions (of HC, CO, and Nox) tolerated in 1990. As standards become stricter, and more countries adopt the use of autocatalysts, demand for platinum will increase.

11.1.3 The jewelry and investment markets

Jewelry is currently the most important area of demand for platinum (41% of world platinum demand). Over the last ten years demand for platinum jewelry has grown by 68%. This growth has been achieved primarily through well planned marketing strategies of PGI. Japan is currently the

largest jewelry consumer, while the largest increase in consumption over the last five years has occurred in China. PGI exploit the fact that Eastern populations favour platinum (for its purity and colour) over other precious metals. In addition, PGI have marketed platinum for specific occasions and thus gained "ownership" of specific markets (such as the bridal market). They are currently active in Japan, China, the USA, Germany, Italy, India and Taiwan. The drive on platinum jewelry marketing is expected to continue, resulting in increasing demand, which ultimately may be moderated by high prices. It is interesting to note that PGI are a subsidiary of the largest platinum producer (Amplats). This allows the producer the opportunity of being more of a price maker than a price taker.

Platinum investment products include, large and small bars, bullion coins and proof coins. The American Eagle is currently the most successful investment product with 175 000 oz demanded in 1998. Investment in platinum is closely related to price, with low prices causing increased consumption of coins and bars. High prices cause platinum to be returned to the market. Japan is the largest consumer in this sector with "accumulation schemes" encouraging increased consumption of investment products. A minimal amount of effort is required for the fabrication of investment products and the author feels that this is an opportune way for producers to benefit from platinum beneficiation. South Africa, the largest supplier and producer, is the only platinum producing country that does not mint its own coins.

11.1.4 Russian supply

Russia currently accounts for about 20% of world platinum supply. The annual supply from this country is, however, highly erratic and difficult to estimate. Analysts find estimation of supply difficult because of the lack of information made available. Perhaps the most important aspect of Russian supply is the size and manipulation of its stockpiles. This

inventory was built up during "cold war" times and is controlled by the Government. The sole producer, Norilsk is forced (by decree) to sell all of its precious metal production to the State. The erratic nature of supply (0.9 Moz in 1997 and 1.3 Moz in 1998). is the result of "strategic" off-loading of platinum from these stocks. The Government appears to withhold metal during low prices and off-load during high prices. Supply from stocks is believed to have augmented the annual amount produced, since 1990. Although estimates of production are highly variable, given the lack of information, the author believes that Russia currently produces 700 000 oz annually. This implies a 2.66 Moz reduction in stockpiles over the last 9 years. The result is that stockpiles must either be exhausted or close to exhaustion. This suggests that Russia will only be capable of supplying a maximum annual amount of 700 000 oz in future. Russian supply is further affected by:

- The fact that platinum is a by-product of nickel production, and therefore dependent on a favourable nickel market.
- The sole Russian producer, Norilsk, has no (or very little) operational capital and there is little hope of foreign investment.
- The prime target reserves (massive sulphides) around existing infrastructure have been exploited and the mine is forced to exploit lower grade, disseminated ores.

Russian supply is a significant component of world platinum supply. Research shows that future annual supply from Russia will drop by about 400 000 oz. In addition, this supply is likely to continue to be erratic, which will force consumers to look for more reliable sources.

11.1.5 Constraints on production

Most of the annual world supply of platinum is derived from primary production (the recovery of platinum from ore). Constraints on production are therefore critical to the steady supply of the metal. Costs, legislation, political stability, availability of labour and commodity status (main-product or by-product) are shown to have a significant affect on production. This

study suggests that estimations of production and the effect of these constraints on production, are best accounted for by studying the "bottle-necks" in each stage of platinum recovery. These "bottle-necks" are identified as mining, milling, floatation, smelting and refining. Each stage has a theoretical maximum capacity of platinum output. An analyst can estimate the annual output of an operation by subtracting the quantity of platinum lost to a disruption, from this maximum.

11.2 The Platinum Supply and Demand Balance

Current world platinum supply for 1998 was estimated at 5.915 Moz. Forecasts of supply in 1999 and 2000 showed totals of 5.595 Moz and 6.000 Moz, respectively. Current world demand for 1998 was estimated at 5.755. A steady 250 000 oz annual increase was forecast for total world demand in both 1999 and 2000. A supply and demand balance shows a resulting 160 000 oz excess in supply for 1998, followed by significant shortfalls of 410 000 oz and 215 000 oz in 1999 and 2000 respectively. The small current excess of platinum is likely to be absorbed by inventories and will have little affect on the price. The large shortfalls of 1999 and 2000, however, are likely to drive up prices, compel consumers to thrift and search for substitutes, and encourage expansion of production. At the time of writing, all major primary product platinum producers are actively expanding production capacity. In addition a number of new projects are being investigated.

12 CONCLUSION

Platinum is a unique commodity. As a rare metal it provides a store of value for the investor, it is irreplaceable in a number of industrial applications and its attraction and purity are greatly desired in jewelry. As a result platinum possess the qualities of both a precious metal such as gold, *and* an industrial commodity such as aluminum. Both qualities are responsible for increasing world platinum consumption. Demand is most significantly driven by; applications in which platinum is irreplaceable, emissions control legislation and marketing strategies employed in jewelry sales.

Annual world platinum supply is affected by production and Russian stockpile control. The majority of primary production is sourced from South Africa who have 68% of the worlds known resources. 20% of supply is currently derived from Russia and the remainder is made up of primary production from the US, Canada and Zimbabwe, and scrap metal recovery. Supply is most significantly affected by constraints on production and the erratic draw-down of Russian stockpiles.

The key to an understanding of the platinum market and price prediction is the estimation of accurate, current and future, demand and supply figures. These figures allow an analyst to derive a balance which will give an indication of whether there is likely to be a shortfall or excess in supply. The magnitude of this difference is related to the reaction the platinum price will have. Current world platinum supply and demand are estimated to be 5.915 Moz and 5.755 Moz respectively. This suggests a 160 000 oz excess for 1998. In contrast, significant supply shortfalls of 410 000 oz and 255 000 oz are predicted for 1999 and 2000. This is likely to drive up platinum prices over the next two years. Where possible, inventories will be used to make up shortfalls, while there will be ever increasing pressure on consumers to find substitutes and to thrift, and

producers to expand operations. In short a favourable market can be expected for platinum, which will continue to serve as a rare, unique and environmentally friendly commodity.

12.1 Further Work

The author identifies two areas that would enhance this study, viz:

- Production constraints are critical to world platinum supply. The effect of disruptions to production is seen at various "bottle-necks" in an operation. These "bottle-necks" occur at well defined stages in the platinum recovery process. The stages are; mining, milling, concentration, smelting and refining. It is suggested that a study of each of these stages, in all platinum operations worldwide would greatly compliment an account of total world supply. The maximum potential platinum production (capacity) should be calculated for each stage at every operation. An evaluation of all disruptions (or constraints) to production should also be made. A good estimation of total world production can be derived if all disruptions to production (in the form of shifts lost) are subtracted from expected maximum production at each stage.

- Supply and demand fundamentals are shown in this study to provide an analyst with a good indication of a future platinum price trend. This indication can be greatly enhanced by a theoretical study of the behavior of the market. It is suggested that a study of price cyclicity, forward contracts and the behavior of other influencing commodities would compliment the supply and demand balance.

APPENDIX

CYCLICALITY

Davutyan and Roberts (1994), prove that most metal commodities "can be described as having some degree of cyclicality, in the sense that there is a duration dependence on the length of phases" These phases or cycles are contractions or expansions in market prices and are clearly seen in platinum spot prices over a period of time. Phases are defined as a period of prices occurring between a price peak and a price trough. The former comprises a price which is higher than at least two years of preceding prices and the latter a price that is lower than at least two years of preceding prices. The work by Davutyan and Roberts (1994) establishes that there is an increased likleyhood of a drop in the price of a commodity as a phase of relatively high prices for that commodity persists. The cycles of commodities can be assessed over varying periods of time. Davutyan and Roberts (1994) suggests longterm, moderate term and short term cycles usually exist for any one commodity. As platinum is traded predominantly in dollars, it is also important to study the cycliscity of the dollar as a commodity, when analysing prices.

REFERENCES

Adams, M. A. P. (1998) *Aquarius Annual Report*, Aquarius Platinum NL, Australia, 1998.

Air Resources Board[1], *Fact Sheet: LEV II Amendments to California's Low-Emissions Vehicle Regulations*, Internet Website (www.arb.ca.gov), California Air Resources Board, United States, Feb. 1999.

Air Resources Board[2], *Fact Sheet: Fuel Cell Electric Vehicles*, internet website (www.arb.ca.gov), California Air Resources Board, United States, April 1999.

Ballington, I. (1999) Amplats Bafokeng Rasimone Nearing Production, Investec Securities Report, (Issue No M199/31), South Africa.

Barnard Jacobs Mellet and Company (1999) Zimbabwe - Platinum Mining Industry, Internet Web Site (www.mbendi.co.za), 1999.

Boyd, L. (1998) *Chairmans Statement, Amplats Annual Report*, Internet Web Site (www.amplats.co.za), 1998.

Brink, M.J. (1999) Platexco Inc. Annual Report 1998, Internet Web Site (www.platexco.com), 1999.

Buchanan, D.L. (1979) Platinum-Group Metal Production from the Bushveld Complex and its Relationship to World Markets, *Bureau of Mineral Statistics Report 4*, Johannesburg, 1979.

Cawthorn, R.G. (1998) The Geology of Platinum Deposits, *Proceedings of the World Platinum Congress*, Johannesburg, Nov. 1998.

Cawthorn, R.G. (1999) The Platinum and Palladium Resources of the Bushveld Complex, *South African Journal of Science*, Vol. 95, pp 481 - 489.

Christian[1], J. M. (1998) Advanced Options and Strategies for Producers, Consumers and Investors, *World Platinum Congress Workshop*, Johannesburg, Nov. 1998.

Christian[2], J.M. (1998) Russian Platinum and Palladium, *Proceedings of the World Platinum Congress*, Johannesburg, Nov. 1998.

Contractor to Play Major Role in New Platinum Venture (1999) *Mining World*, Feb. 1999.

Cook, S. (1998) Promoting Consumption of Platinum Coins as an Investment Vehicle, *Proceedings of the World Platinum Congress*, Johannesburg, Nov. 1998.

Courage, J. (1998) The Development of Effective Marketing Programmes to Stimulate Demand for Platinum jewelry and Coins, *Proceedings of the World Platinum Congress*, Johannesburg, Nov. 1998.

Courage, J. (1999) *PGI Presentation to Lonmin South Africa*, Platinum Guild International, United Kingdom, Nov. 1999.

Cowley, A. (1998) The Growth in Demand for Platinum Jewellery, *Proceedings of the World Platinum Congress*, Johannesburg, Nov. 1998.

Crankshaw, P. ed (1999) Exploration - Country Updates, *African Mining*, Vol 4, No 4, pp 13 - 14.

Crankshaw, P. ed (1998) Messina Marks Southern Era's Debut into platinum, *African Mining*, Vol 3, No 2, pp 33-34.

Davidson, B. (1998) Overview of the Platinum Group Metals Business, *Proceedings of the World Platinum Congress*, Johannesburg, Nov. 1998.

Davuŧyan, N. And Roberts, M. C. (1994) Cyclicality in Metal Prices, *Resources Policy*, Vol 20 (1) pp 49 - 57.

Emmett, D. (1998) An Overview of Platinum Group Metals Markets, *Proceedings of the World Platinum Congress*, Johannesburg, Nov. 1998.

Evans, D. (1998) Kroondal Platinum project, *Proceedings of the World Platinum Congress*, Johannesburg, Nov. 1998.

Falconbridge, *Internet Website* (www.falconbridge.com), May. 1999

Forrest, S.A. (1998) Global Platinum Shares and Producers, *UBS Global Research Report*, Switzerland, Feb. 1998.

Hiemstra, S.A. (1985) The Distribution of Some Platinum Group Elements in the UG2 Chromitite Layer of the Bushveld Complex, *Economic Geology*, Vol. 80, 1985, pp 944 - 957

Hochrieter, R. (1998) Analysing the Impact of Russian Production on Market Prices, *Proceedings of the World Platinum Congress*, Johannesburg, Nov. 1998.

Hunter, G. (1998) PGM Economic Aspects, Quality and Pricing, *Proceedings of the World Platinum Congress*, Johannesburg, Nov. 1998.

Inco, Internet Website (www.inco.com), May 1999.

Jagger L. (1999) Shallow Platinum Mining in South Africa, *Presentation to the South African Institute of Mining and Metallurgy*, Oct. 1999.

Johnson Matthey, Cutting Vehicle Pollution Today and Tomorrow, Internet Website (www.matthey.com), Nov. 1999.

Johnson Matthey[1], *Noble Metals Report*, United Kingdom, 1997.

Johnson Matthey[2], *Platinum 1997*, United Kingdom, 1997.

Johnson Matthey, *Platinum 1998*, United Kingdom, 1998.

Johnson Matthey, *Platinum 1999*, United Kingdom, 1999.

Jones[1], A. (1999) SA Mining's Labour Pains, *African Mining*, Vol 4, No 5, pp 48 - 49.

Jones[2], R.T. (1999) Platinum Smelting in South Africa, *South African Journal of Science*, Vol. 95, pp 525- 534.

Mc Mahon, J. M. (1999) Implats Annual Report, Internet Website (www.implats.co.za), 1999.

Mc Cutcheon, B. (1996) *Platinum Group Metals*, Canadian Minerals Yearbook 1996, Canada.

Mc Kay, D. (1999) Platinum Demand to "Outstrip" Supply *Internet Website* (www.bday.co.za), 1999.

Naldrett, A.J. (1989) Platinum-Group Element Deposits, *Platinum-Group Elements: mineralogy, geology, recovery Special Volume 23*, Canadian Institute of Mining and Metallurgy, Montreal, 1989, pp 197 - 231

North American Palladium, Lac Des Isles Mines, *Internet Website* (www.napalladium.ca), 1999.

Norilsk Nickel, *Internet Website* (www,nornik.ru), Nov. 1999.

Nurdin, M.A.B. (1998) PGM's and the Greening of the Automobile Converting Catalysts to Fuel Cells, *Proceedings of the World Platinum Congress*, Johannesburg, Nov. 1998.

Nutt, T. (1999) Zimbabwe's Platinum: Is there Life After Hartley, *African Mining*, Vol 4, No 4, July 1999, pp 57 - 59.

Okafor, V.I. And Coville, N.J. (1999) Platinum in Catalysis, *South African Journal of Science*, Vol. 95, pp 503 - 508.

Pittendrigh, P. (1999) Why Platinum is a Perpetual Winner, *Finance Week*, Oct. 1999.

Platinum the Most Precious Precious Metal, This Week in Platinum, *Internet Website* (www.researchmag.com), Nov. 1997.

Platinum Market Observations, *Internet Website* (www.platinumguild.org), Dec. 1999.

Radetzki, M. and Tilton, J. E. (1988) *Conceptual and Methodological Issues*, 1988, pp 13 -34.

Stillwater Mining Company, *Internet Website* (www.stillwatermining.com), 1999.

Swiss America, More About Bullion Products, *Internet Website* (matrix.binary.net), Dec. 1999.

Takada, A. (1999) Tokyo Palladium Solid Despite Russian Plans, *Internet Website* (www.financialexpress.com), Dec. 1999.

Taylor, S.S. And Biggs, T. (1999) Innovations in Platinum Jewelry Materials, *South African Journal of Science*, Vol. 95, pp 543 - 549.

The South African Code for Reporting of Mineral Resources and Mineral Reserves, SAMREC Draft Code, 1999.

Tilton, J.E. (1985) Economics of the Mineral Industries, *Mining Engineering Handbook*, Chapter 2.1, USA, 1985.

Vermaak, C.F. (1995) *The Platinum-Group Metals, A global Perspective*, South Africa, Mintek, 1995.

Viljoen, M. (1998) An Overview of Global Platinum Deposits, *Proceedings of the World Platinum Congress*, Johannesburg, Nov. 1998.

Viring R. (1998) Deep Mining Technology in Platinum Mines, *Proceedings of the 8th International Platinum Symposium*, Rustenburg, Nov. 1998.

Wilkinson, T.A. (1998) Chairmans Review Lonrho Platinum Annual Report, South Africa, 1998.

Winter 1998: *Russia and Asia Loom Large Over the Platinum Market*, This Quarter in Platinum, Internet Website (www.platinumguild.org), 1998.

Wright, A.J. (1999) *Chairmans Review, Northam Platinum Limited Annual Report*, Internet Website (www.gfsa.co.za), 1999.

Young, G. (1998) Autocatalysts, *Proceedings of the World Platinum Congress*, Johannesburg, Nov. 1998.

Author Mauve A C
Name of thesis The Platinum Market Fundamentals Affecting Supply And Demand Mauve A C 2000

PUBLISHER:
University of the Witwatersrand, Johannesburg
©2013

LEGAL NOTICES:

Copyright Notice: All materials on the University of the Witwatersrand, Johannesburg Library website are protected by South African copyright law and may not be distributed, transmitted, displayed, or otherwise published in any format, without the prior written permission of the copyright owner.

Disclaimer and Terms of Use: Provided that you maintain all copyright and other notices contained therein, you may download material (one machine readable copy and one print copy per page) for your personal and/or educational non-commercial use only.

The University of the Witwatersrand, Johannesburg, is not responsible for any errors or omissions and excludes any and all liability for any errors in or omissions from the information on the Library website.