Platinum Group Metals in SA

Geology

The Bushveld Igneous Complex (BIC), which extends for 400 kilometres in the Northern Province, contains the world's largest known deposits of platinum group metals (PGMs) - platinum, palladium, rhodium. ruthenium. iridium and osmium. It is a large igneous (volcanic) intrusion through the earth's crust which having been tilted and eroded new outcrops to surface around what appears to be the edge of a great geological basin.

The BIC system is divided into an eastern and western lobe with a further northern extension: it is believed that all three sections of the system were formed around the same time - about 2 billion years ago -- and are remarkably similar. Vast quantities of molten rock from the earth's mantle were brought to surface through long vertical cracks in the earth's crust creating the geological intrusion known as the BIC. The effects of these injections of molten rock over time, combined with the crystallisation of different minerals at different temperatures, resulted in the formation of a structure rather like a layered cake consisting of distinct mineral strata, including three PGM-bearing reefs.

Reserves

The unique BIC contains estimated PGM reserves of 62 816 tons, about 55,7 per cent of the world total. So far, the Merensky Reef has been the source of most of South Africa's PGMs. It is estimated to contain some 17 000 tons of PGM, reserves. In the western BIC, where the major platinum mines are situated, the reef occurs in a narrow, 25- centimetre-wide PGM rich band bounded by two thin chromite layers. This pattern falls away in other areas resulting in the reefs diverging between the chromite bands until it is many metres wide The Merensky Reef is characterised by its high PGM grades and the high ratio of platinum to the other PGMs, especially those of major importance like palladium and rhodium.

The UG2 Reef, which is more consistent throughout the BIC, is rich in chrornite, but lacks the Merensky's gold, copper and nickel by-products, though its PGM reserves may be almost twice as large as those of the Merensky Reef. It is estimated that increasing exploitation of the UG2 Reef will lift its contribution to South Africa's platinum output. The Crocodile River mine was the first devoted entirely to exploiting UG2 ore.

In the northern extension of the BIC the Platreef is found. Whereas the platinum palladium ratio in the Merensky and UG2 reefs is close to three to one, the two metals are found in equal measure in the Platreef deposits.

Production

Platinum group metal mines have expanded consistently over the past 10 years, resulting in production increasing from 1522,9 tons in 1992 to 216,5 tons in 1999. Sales of the product locally soared from a negligible amount in 1995 to R2,5 billion in 2000. There are two major reasons for this. First, the Motor Industry Development Programme promotes the export of car components, including catalytic converters. Secondly, the jewellery industry used about 200 kg of platinum in 2000.

Year	Production kg	Export sales R'000
1990	141 913	5 164 216
1991	142 861	5 692 062
1992	152 891	4 677 841
1993	176 167	5 188 809
1994	183 926	5 809 613
1995	183 097	6 572 506
1996	188 636	7 428 137
1997	196 604	8 403 862
1998	199 953	11 602 274
1999	216 479	13 964 729

Mining Platinum

The mining of platinum ores is similar to gold mining inasmuch as the orebody is a thin, tabular reef covering an extensive area. This enables a progressive method of mining - the reef is drilled and blasted to advance the face, support being installed for local control of the hanging w all. As in gold mines, platinum mining is incorporating the increased use of mechanisation and trackless-mining methods in stopes little more than one metre high.

Platinum mining, how ever, differs from gold mining in several w ays. Unlike gold reefs, w hich are sedimentary deposits resulting from the settling of granular particles on the bed of an inland lake and subjected to great pressure, platinum reefs are igneous rocks. They w ere intruded into the Bushveld area as molten volcanic magmata rising from below the earth's crust, later cooling and solidifying. This phenomenon created a strata control environment differing markedly from that of gold mines.

Platinum mining is also affected by a further geological feature - the occurrence of parboils in the plane of the reef. Varying in diameter from some 30 to 500 metres, and causing rapid sinking or rising of the reef, these potholes disrupt stoning operations, often requiring the re-establishment of stone faces.

Occurrence of PGMs

The Merensky Reef is the source of over 80 per cent of the platinum mined in South Africa This has been successfully exploited since the late '20s.

More PGMs are found in the chromatite reefs of the BIC. The highest PGM values are associated w ith the UG2 Reef w hich lies about 200 metres below the Merensky. Since the mid '70s increasing tonnages of UG2 ore have been mined and treated by the established producers.

Smaller quantities of PGMs are found in the middle and low er group chrome seams w hich are mined for their chrome content. Recently, some of these PGMs have been recovered by re-treatment of chrome mine railings. Other similar schemes are planned, though the quantities of precious metals from this source w ill never be very large.

The PGM-bearing Platreef occurs in the northern portion of the BIC. Mining of this reef w as discontinued in the early '30s ow ing to treatment difficulties and patchy values. Exploration and test-work have continued and at least one new mine is now planned for the Platreef.

Mineralogy

The pattern of values in different ore samples can vary widely. The precious metals occur in a variety of forms. One or more of the metals may be present in combination with sulphur, arsenic, selenium or tellurium metallic particles of PGMs or of PGMs alloyed with base metals are also found. Additional PGMs are found in solid solution in base metal sniphide particles.

Chromite crystals form a large part of the volume of UG2 and other chrome ores. Base-metal sulphides are much more prevalent in Merensky and Platreef ores than in the UG2 or chrome ores. The grain size of mineral particles varies widely but is coarsest in Merensky ores.

The difficulty in recovering PGMs from any particular ore is determined by the ore's mineralogy. Although Merensky ores are often easier to treat, it is not easy to generalise. Ore from different areas of the same mine can have quite different characteristics.

Recovery Processes

PGM recovery processes for UG2 and Merensky ores are generally similar. However, the disparity in base metal contents is responsible for differences in the relative scale of some unit operations. Processes can be grouped into the four stages of concentration, smelting, base metals removal, and precious metals refining.

Concentration

In concentration. the ore is ground to liberate mineral particles. These are then recovered in the form of a concentrate by froth flotation. The ore mineralogy dictates both the fineness of grind required for liberation and the ideal flotation conditions. Very fine particles are difficult to recover, so two or even three milling and flotation stages may be used to minimise losses caused by over-grinding.

There are minor differences in the details of the equipment and operations employed by the various producers. In Merensky processing a metallic concentrate rich in PGMs is sometimes produced in addition to the flotation concentrate. This concentrate can be sufficiently rich to by-pass the smelter and be sent straight to base metal removal.

In UG2 processing there are a number of options regarding by product chromite recovery and blending with the Merensky ore before milling. At present, though, only one South African producer is recovering chromite: this is done after primary milling, with the chromite crystals being liberated at their natural grain size. UG2 ores require finer grinding than Merensky are for optimum PGM recovery. Blending of the two before milling therefore gives lower recoveries and is to be avoided where possible.

Smelting

The concentrate is melted in an electric furnace. Large units with six electrodes in line are used for smelting Merensky or mixtures of Merensky and UG2 concentrates. Smaller circular furnaces are used to smelt unblended UG2 concentrate. On melting, the concentrate separates into two layers. The upper layer is a silicate/oxide slag w hich is tapped off and then either discarded or returned to concentration. The low er layer is a sulphide motto w hich is sent for converting.

The flotation-concentrate composition must be suitable for smelting. its rock mineral content should produce a fluid slag at the desired temperature. At the same time, it must contain enough sulphides to form a reasonable quantity of matter. To compensate for minor problems w ith chemical composition, various fluxes are added. Typically, the main addition is burnt lime or limestone but other materials such as carbonaceous reductants, sulphides, oxides or silicates are used as necessary.

Higher temperatures are required to melt UG2 concentrates ow ing to higher contents of chromium and magnesium oxides. More turbulent smelting conditions are also preferred to avoid build-up of chrome spinel in the furnace hearth. Crocodile River Mine w as the first operation to be dependent on smelting unblended UG2 concentrates. Other operators have been able to feed their furnaces w ith a blend that includes Merensky concentrate.

The furnace matte is further processed by converting. Excess sulphur and iron are oxidised in a refractory lined vessel. Fluxing agents are added to form an iron-rich slag that is skimmed off and returned to the furnaces. The converter motto is then sent for base-metal removal.

Base-metal Removal

Base metals are removed from the converter matte either by leaching or by a combination of magnetic separation and leaching processes. Problem elements such as selenium, arsenic and tellurium are also removed. The concentrate w hich results is sent for further processing into refined precious metals. Base metals are a valuable by-product of PGM extraction. Their further refining by the various producers is largely dictated by economies of scale.

Precious Metals Refining

Precious metals refining processes have developed considerably in recent years. The older or 'classical' process involved first roasting the PGM concentrate. This made the rhodium, iridium and ruthenium insoluble in aqua regia. The platinum, palladium and gold w ere then dissolved and separated by a series of sequential precipitations, The remaining residue w as then upgraded by pyro-metallurgical and leaching processes before being separated into individual metals. Final purification of all metals w as by repeated dissolution and precipitation.

Improved separation and refining procedures have become available for all of the precious metals. These commonly involve operations such as solvent extraction or ion exchange. They are being introduced either to replace procedures in the classical process or as part of completely new refining processes. Advantages such as improved precious metals recovery, low er refining costs and shorter processing times are being claimed.

PGMs - The Major Demand Sectors

The extraordinary physical properties of the platinum group make its metals almost indispensable in a w ide range of industrial applications.

Autocatalysts

Motor vehicle exhaust systems are fitted with catalytic converters to reduce the polluting effects of exhaust emissions. The converter's main component is a ceramic honeycomb, the surface of which is coated with platinum and rhodium, to which palladium is sometimes added. The main form of autocatalyst is a three way converter, so called because as engine exhausts pass through the converter at around 300°C, these precious metals convert nitrogen oxide, unburnt hydrocarbons and deadly carbon monoxide into harmless nitrogen, water and carbon dioxide.

Autocatalysts, which account for more than 40 per cent of total demand for platinum alone, are the major demand sector for PGMs - and for the next few years this market is unlikely to see any economically viable substitutes for these metals. It is believed that total autocatalyst demand for platinum was some 1.5 million ounces in 1989. Palladium supplies to the industry in 1989 amounted to 265 000 ounces. In the same year record amounts of rhodium, a rare metal, far more expensive than platinum, were used in autocatalyst manufacture: autocatalysts accounted for 79 per cent of total rhodium demand of 330 000 ounces, around 56 per cent being supplied by South Africa.

The major industrialised countries of the world - spearheaded by the United States, Japan and, most recently, the European Community member states are enacting legislation to apply increasingly stringent auto emission standards, in spite of developments like lean-burn engine technology (which aims at complete petrol combustion), and Ford's claims (subsequently shown to be exaggerated) regarding a new type of platinum-free, palladium oxidation catalyst, for the foreseeable future platinum/palladium/rhodium catalysts are likely to be the overwhelming choice of motor manufacturers worldwide. Autocatalyst demand, and especially that for the three way converters with their higher unit loadings of precious metal, continues to be encouraging. As a result of the European Parliament's series of votes in favour of tighter emission controls, 80 per cent of European cars were required to carry three way catalytic converters by 1993.

Jewellery

Today, around 38 per cent of the world's platinum finds its way into jewellery. Japan, which accounts for almost half of total free market demand for the metal, is by far the world's largest consumer of platinum for jewellery fabrication. Japan has traditionally favoured the metal over gold or silver. Elsewhere sales of platinum appear to have improved in other countries in the Far East and climbed steadily in the two major European markets, Italy and Germany.

Investment

Platinum has established a recognition for itself as a legitimate, complementary holding to gold and silver, primarily in that country, and also the United States and Western Europe. As growing evidence of this Johnson Matthey (UK marketing agents), as well as the Chinese, Australian, Canadian and former USSR governments, all launched platinum coins and medallions on to the market, with the Canadian Maple Leaf, the Isle of Man Noble and the Australian Koala dominating the legal tender coin investment sector.

Industry

In this sector, demand essentially arises out of the servicing of platinum requirements to make up losses incurred in use and through recycling. Any growth, therefore, is largely dependent on the establishment of new capacity, although new applications for PGMs continue to be discovered in a widening range of industries.

PGMs continue to maintain their long association with the electrical and electronics industry, which accounts for 50 per cent of annual palladium and ruthenium demands. Although traditional usage of PGMs in electrical contacts has declined, the 'micro-chip' era opened up a wide range of novel electronic applications. The use of iridium crucibles at very high temperatures for growing single crystals of specialised electronics materials is but one example demonstrating that PGMs are proving indispensable in many facets of electronics technology.

In the chemicals industry, the most important area of application for PGMs is in the production of nitric acid, essential for fertilizer and explosives manufacture and a host of other chemical uses. In the electro-chemical sector, ruthenium and iridium are used to coat electrodes for the production of chlorine, while iridium is employed in petroleum refining and other catalysts.

Platinum is essential to the petro-chemical industry. It is used as a reforming catalyst in the production of higher-octane fuels and the more complete exploitation of the various fractions of crude oil World demand for oil is recovering. which is resulting in more platinum and other PGMs such as iridium being needed to top up considerable stocks of reforming and isomerisation catalysts, while upgrading of refining capacity and construction of new isomerisation capacity will lead to greater demand. In addition, as the petroleum industry has pruned much excess capacity, the resultant sale back to the market of platinum recycled from spent catalyst has slowed down.

PGMs are used in the glass industry in two principal fields - glass fibre, and other optical and high-performance glass. in glass-fibre product/on, the fibres formed as molten glass are extruded through fine bushings. These are invariably made of rhodium/platinum alloys [n the case of optical and high-performance glass used in camera and instrumentation manufacturing, video equipment and television, there is still no substitute for platinum. Other areas of growth for platinum include catalysts for air pollution control, water purification and electrodes for cathodic protection against erosion.

Finally, motor manufacturers are introducing platinum-tipped spark plugs that offer longer life and improved combustion and fuel efficiency.

Medicine

Palladium is rapidly supplanting gold in dentistry. Platinum is used in the treatment of certain types of cancer. In the future PGMs may play a role in fighting viral. bacterial and parasitic infections: they may also come to be used as diagnostic tools.

Fuel Cells

The clean and efficient fuel cell of the future, in which platinum catalysts are used to convert the chemical energy of a fuel into electrical energy, has for some time been seen as the next new major demand sector in the industrial area. Two problems plague further moves to achieve wide commercialisation of fuel-cell systems which utilise a platinum catalyst. Firstly, the current high capital cost of the pro-production units makes them uncompetitive: secondly, proof of reliability can only be achieved through demonstration of the generating plants. It is forecast that there will be an increasing call for these types of cell in specialist applications, such as in the aerospace, defence and leisure industries.