Platinum Mining at Rustenburg

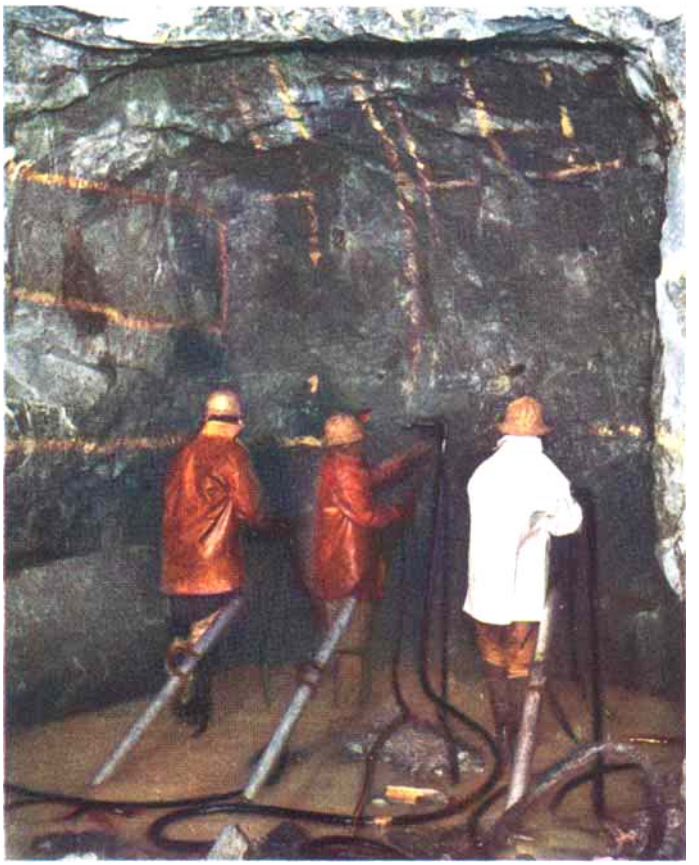
GROWTH OF THE WORLD'S LARGEST PRODUCER

The scale of operations at Rustenburg Platinum Mines has been extended many times over the last thirty years to meet increasing demand, the most recent expansion programme providing for an output of one million ounces of platinum a year. This article describes the mineral resources available and the mining methods and extraction processes in use to provide the world's largest source of the platinum metals.

Demand for platinum has increased substantially over the past ten years or so, and indications for the next few years are that no slackening in the pace is to be expected. Of the three principal sources, Rustenburg Platinum Mines in South Africa, International Nickel in Canada, and the Russians, only one, Rustenburg, has been able to respond significantly to increased demand because the South African mines are worked primarily for the platinum metals and yield copper and nickel as by-products, whereas elsewhere the converse is the case. Rustenburg is in fact the world's largest single source of platinum and the only major mine whose main business is the production of the platinum metals.

The pattern of expansion at Rustenburg is familiar to readers of this journal. Output has

The upper levels of the mine are still being worked from incline haulage systems, but these are followed in depth by vertical shafts. The headgear for the most recent addition, known as the Frank shaft, is now in course of construction. This will exploit the ore body to a depth of 3,000 feet



A machine crew drilling holes for blasting in the development end of a haulage tunnel

been increased from some 200,000 ounces of platinum in 1963 to 850,000 ounces a year at present, with a further expansion programme in hand to yield 1,000,000 ounces a year by 1971. Corresponding increases have, of course, taken place in the output of the other members of the platinum group of metals – palladium, rhodium, ruthenium, iridium and osmium.

This has been achieved by very substantial capital expenditures on the sinking of new shafts, the installation of additional grinding, milling and flotation equipment, and the building of an additional modern smelting plant, together, of course, with a consequent expansion in all the facilities and services, including the housing of some 20,000 employees. The expenditure involved in the expansion programme over the seven years 1967 to 1973 will probably exceed £37 million.

Today Rustenburg constitutes the largest underground mining operation in the Republic of South Africa, its two mines together extending more than eighteen miles from one end to the other, and providing about 60 per cent of the Western world's needs of platinum.

Relating Supply to Demand

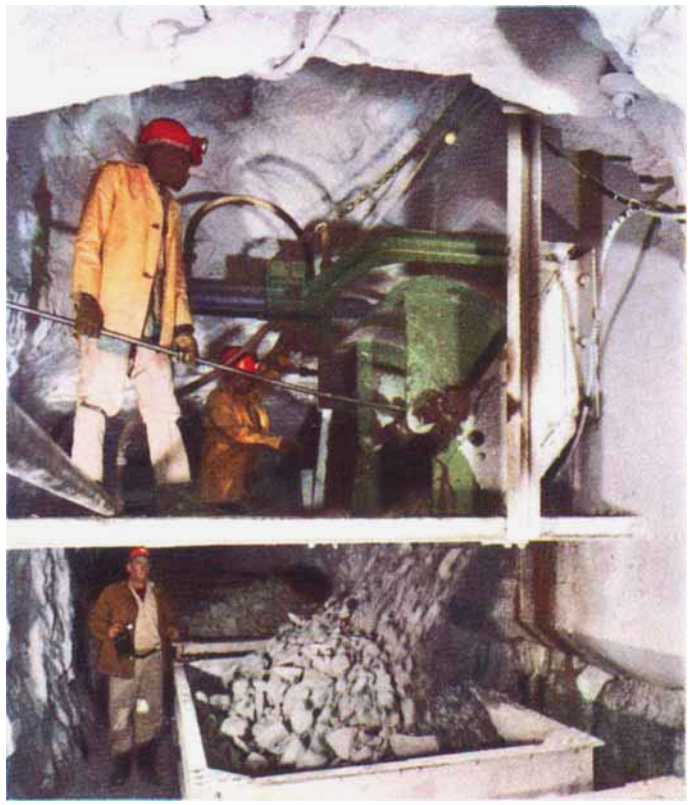
One of the problems faced by Rustenburg – and by Johnson Matthey as its refiner and distributor – is the forecasting of demand in the face of the hard fact that a decision to expand output does not result in an increase in the supply of refined metal for a full three years. Decisions to expand, involving many millions of pounds and taken on the best available data, can therefore be vulnerable to changing conditions, and this lengthy period between conception and realisation has inevitably led to criticism by some users whose

predictions of future needs were too cautious or too tentative. Forecasting demand necessarily depends upon reliable projections from users and potential users, who in turn have their own uncertainties to consider. Fortunately, when predictions of demand turn out to need revision, Rustenburg is capable – given the necessary time – of expanding its operations very considerably. At any presently conceivable rate of production the ore reserves known to be available will ensure continuity of operations well into the next century.

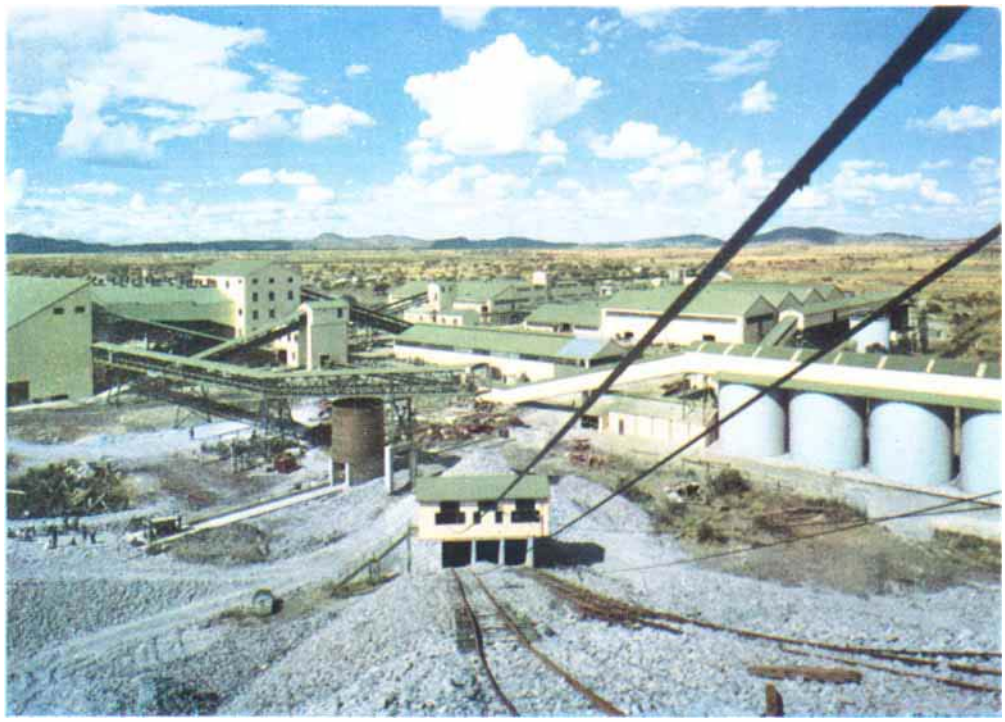
Because platinum is capable of being recovered from many of its important fields of application and used again, a continuing demand for increased supplies of new metal depends upon a steady growth in technologically advanced industries. During the last five years the consumption of newly-mined platinum has been accounted for as to approximately 30 per cent in the chemical industry, about 25 per cent in petroleum reforming, 20 per cent in electrical and allied uses, and 10 per cent in the glass industry, with some 15 per cent covering dental, medical, jewellery and miscellaneous applications. Thus the use of platinum is not associated with one or two industries, and many of its applications are in areas of industrial growth.

Mineral Resources

The deposit worked by Rustenburg Platinum Mines forms part of the Merensky Reef of the Bushveld Igneous Complex. This reef, named after the geologist Hans Merensky who was responsible for the prospecting programme that led to its discovery in the 1920s, is shown in red on the map on page 20. It has been traced on outcrop a distance of some 75 to 80 miles along both the eastern and western limbs of the Complex. The eighteen miles of outcrop which are mined at



From the working face the platinum ore is loaded into small panel cars, tipped into a central gulley and then scraped into a stope box. Here it is being transferred from the stope box into haulage cars for conveyance to the surface



A general view of one of the reduction plants taken from the waste rock dump. The operations carried out here include crushing the ore, milling and flotation

the two operations, the Rustenburg section a few miles to the East of the town, and the Union section about sixty miles to the North, are considered to contain the highest grades of the entire igneous complex – most of the remainder containing lower grades which will no doubt be profitably turned to account some time in the future.

The reef at Rustenburg dips at approximately 10° to the north-north-east, but the dip steepens to about 22° at the Union section. Platinum values at these two sections show a very even tenor, the platinum being partly in the form of native metal, invariably alloyed with iron as ferro-platinum, and partly as the sulphide, arsenide and sulph-arsenides, these always occurring in intimate association with the sulphides of iron, copper and nickel. Associated with platinum, the predominant metal, are smaller proportions of palladium, ruthenium, rhodium, iridium and osmium, in descending order.

The platinum bearing reef averages only some twenty inches in thickness, but its regularity makes for relatively straightforward mining. The dip and strike of the ore bodies on each property are consistent, and although an occasional dyke is met with there is generally an absence of faulting. Although the Merensky reef persists to depths beyond the limits of practical mining, the reserves down to a depth of 3,000 feet are immense.

Mining Methods

The length of strike and the comparative shallowness of the deposit have made possible the rapid development of large areas of ground whenever a greater demand for platinum has arisen – one reason why Rustenburg has been able to follow world demand so closely. In both sections mining technique is virtually the same. In the shallower portions of the deposit inclined haulages are sited about 2,500 feet apart and are connected by drives on reef. The deeper

areas have been opened up by means of four vertical shafts ranging in depth from 500 to 2,000 feet, while two further shafts are currently being sunk to exploit the ore body to a depth of 3,000 feet.

From the shaft systems a network of cross-cuts and haulages extends to intersect the ore body, and shallow gullies divide the working face into panels. Ore broken on the face is washed down, loaded into small panel cars and tipped into a central gully, from which it is removed by a scraper winch into a stope box and loaded into trains of 4-ton hopper trucks hauled by electric locomotives conveying the ore to the shaft for hoisting to the surface.

A great deal of thought and investigation has gone into the laying down of standard working methods to ensure the delivery to the mill of a product of the highest value at the lowest cost.

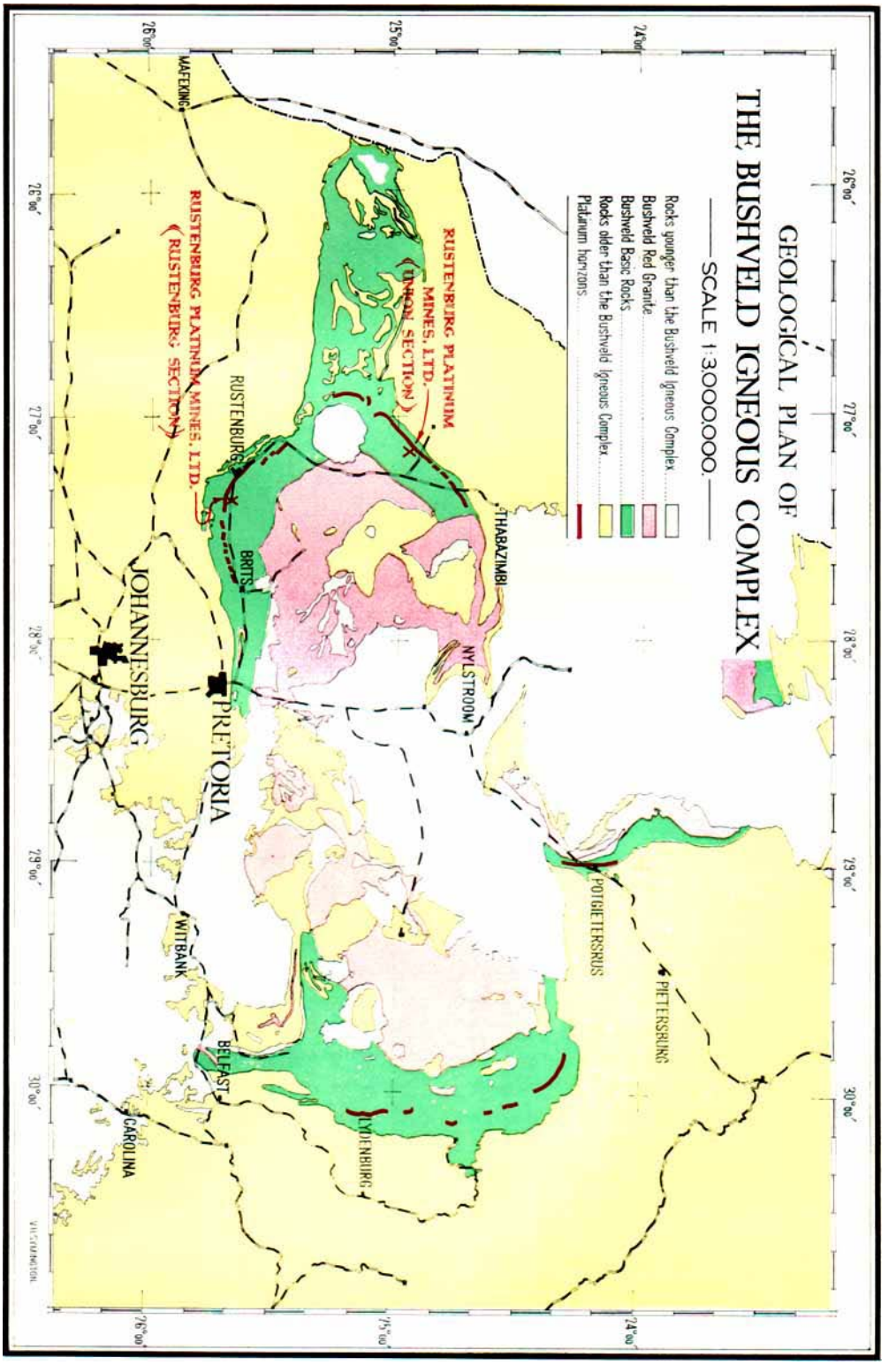
Reduction Practice

Treatment of the ore, comprising crushing, ball milling, gravity concentration and flotation, is carried out in two reduction plants, an older unit and a more modern mill erected in the last few years, while a third mill is now in course of construction to handle the increased output.

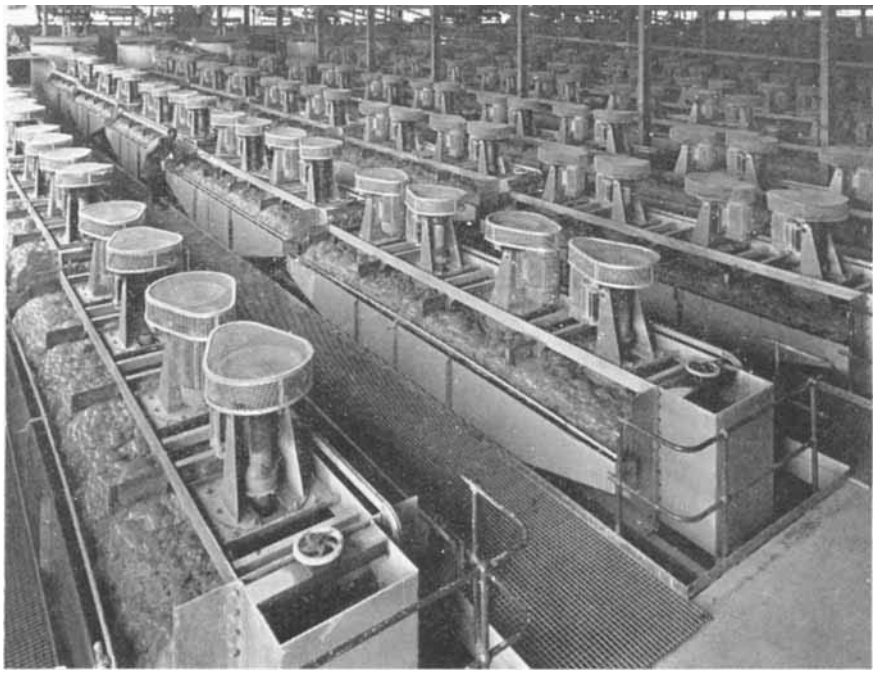
The ore is first crushed in a series of jaw crushers and fed to the primary and then the secondary ball mills which are in closed circuit with hydrocyclone classifiers. This is followed by gravity concentration on corduroy tables to separate the course particles of platinum-bearing minerals and the free metallic particles. The corduroy concentrate is dressed on an elaborate system of shaking tables up to a final high grade concentrate which is sent directly to the Johnson Matthey refineries in England.

The tailings from the tables are returned to the mill circuit, the final pulp from here being treated in a series of thickeners before going to the flotation plant. Here banks of cells are arranged in a normal rougher-cleaner circuit which recovers most of the remaining platinum-bearing minerals. The flotation concentrates, consisting mainly of nickel,

After preliminary crushing the ore is fed to the primary and secondary ball milling sections



The location of the platinum-bearing Merensky reef is shown in red, together with the two mines operated by Rustenburg Platinum Mines



One of the flotation plants at Rustenburg. The concentrates are thickened, filtered, dried, and pelletised before smelting to a matte

copper and iron sulphides with the balance of the platinum metals, are thickened, filtered, dried and pelletised, ready for the smelter while the tailings are dumped.

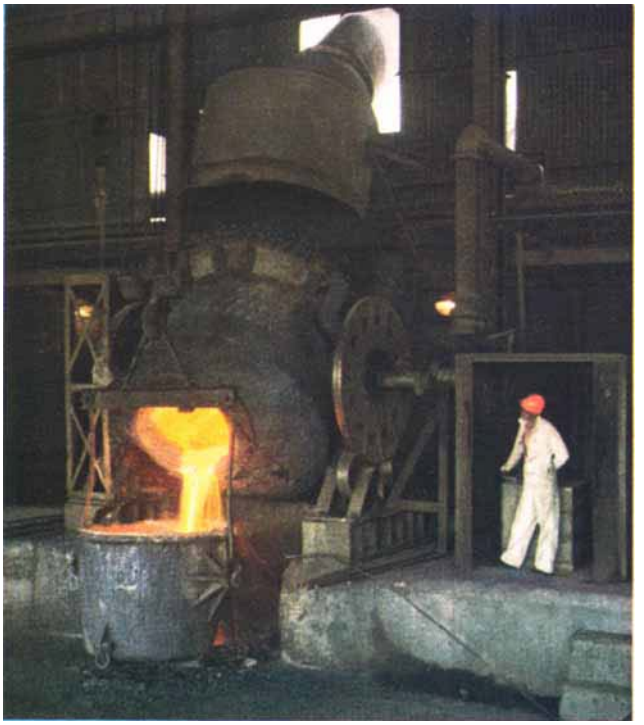
Smelting and Refining

The initial stage in the recovery of the platinum metals is to smelt to a copper-nickel-iron matte in a series of blast furnaces. This matte is then tapped periodically into ladles, transferred to a group of converters, and blown to a high-grade matte which is cast into moulds and then broken up in a jaw crusher. Part of this converter matte is shipped to the Johnson Matthey smelter in England, the balance being treated by Matte Smelters, a joint subsidiary of Johnson Matthey and Rustenburg, in a plant adjacent to the mine. In both plants the matte is treated by smelting to separate the copper and nickel sulphides. The copper sulphide is blown in converters to give blister copper which is cast into anodes, while the nickel sulphide is roasted, reduced to metal in reverberatory furnaces and also cast into anodes. Both the copper and the nickel anodes are electrolytically refined to pure metals, the platinum group metals being recovered in the form of adherent anode residues.

At the two matte treatment plants in South Africa and in England new and improved processes have been introduced in which the nickel and copper are separated more efficiently and the platinum metals are further enriched.

Final concentration and separation of the platinum metals is carried out in the Johnson Matthey refinery in England, but an additional refinery is now under construction in South Africa to supplement supplies by treating some part of the output of Matte Smelters.

After roasting and leaching to remove the last of the copper, nickel and iron, the enriched anode residues join the platinum-bearing gravity concentrates shipped from South Africa and together enter the wet process refinery, where the platinum metals are brought into solution for their separation and individual refining. The complete cycle of treatment is very complicated but basically



Pouring blown matte from one of the converters. After casting and breaking up, the matte is shipped to Johnson Matthey for the extraction of copper, nickel and the six platinum metals

it involves their precipitation as complex salts followed by successive stages of recrystallisation and then by calcination under carefully controlled conditions in electrically heated muffle furnaces, to produce the metals in the form of sponges or powders suitable for melting.

From this refinery, which has of course been enlarged in line with the Rustenburg expansions, the six platinum metals are supplied in pure form to independent fabricators and catalyst manufacturers and to the Johnson Matthey group of companies throughout the world.

Throughout all the stages of extraction and refining new and improved methods are under constant development, and the numerous extensions to plant both at Rustenburg and in the Johnson Matthey refineries have been designed to take full advantage of more sophisticated metallurgical techniques.

Osmium Complexes Containing Four Metal Atoms

The preparation of interesting new complexes containing four metal atoms has been reported by C. W. Bradford, of the Johnson Matthey Research Laboratories, working under the guidance of Professor Sir Ronald Nyholm (*Chem. Comm.*, 1968, 867). These are obtained by reacting osmium carbonyl, $Os_3(CO)_{12}$, with triphenylphosphine gold halides. It appears that only one of the three Os-Os bonds in the original triangular cluster is broken and this gives rise to what is possibly the first case of a linear arrangement of four covalent bonded metal atoms:

$$Ph_3PAuX + Os_3(CO)_{12} \rightarrow$$

$$Cl - \underset{(CO)_4}{Os} - \underset{(CO)_4}{Os} - \underset{(CO)_4}{Os} - AuPPh_3$$

This new compound is red in colour, monomeric and a non-conductor in solution, and has an infra-red spectrum in the C-O stretching region which is consistent with a linear arrangement of the Au-Os-Os-Os moiety.

The corresponding bromo-compound:

$$Br - \underset{(CO)_4}{Os} - \underset{(CO)_4}{Os} - \underset{(CO)_4}{Os} - AuPPh_3$$

has also been isolated and has properties similar to those of the chloride.

If X-ray crystallographic studies at present being made show that a linear arrangement is indeed present, then it is interesting to speculate on the possibility of synthesising from these compounds other compounds containing even longer chains of metal atoms.