SPOTLIGHT
on GOLD 100

by H.E. JAMES*

GOLD 100, the most comprehensive international conference on gold ever held anywhere in the world, took place in Johannesburg from 14th to 18th September, 1986. The Conference was followed by a series of one-day visits and an extended technical tour.

The Conference was organized jointly by the Council for Mineral Technology (Mintek), the Chamber of Mines of South Africa, the School of Business Leadership of the University of South Africa, and The South African Institute of Mining and Metallurgy.

Registration

GOLD 100 was unique in that it covered both technical and marketing aspects, thus attracting not only mining engineers, metallurgists, mine managers, industrial users of gold, and economists, but also gold dealers, investment advisers, bankers, stockbrokers, government officials, and members of the financial and technical press.

Delegates at the official opening of GOLD 100

The total registrations amounted to 699 delegates and 78 affiliates. Altogether, 165 of the delegates were from outside the Republic of South Africa, representing the following 20 countries: Australia, Belgium, Brazil, Botswana, Canada, Chile, France, Greece, Hong Kong, Iceland, Italy, Japan, Luxembourg, Peru, Switzerland, the United Kingdom, the United States of America, Venezuela, West Germany, and Zimbabwe.

Official Opening and Plenary Addresses

Mr Peter Gush, President of the Chamber of Mines, delivered the opening address on Monday, 15th September, 1986, exactly one hundred years *to the day* after the proclamation of the Witwatersrand goldfields by President Paul Kruger (*Staatscourant*, Zuid-Afrikaansche Republiek, Pretoria, Woensdag, 15 September 1886).

The following plenary addresses were delivered during the Conference:

The South African economy with particular reference to the importance of the gold-mining industry
Mr Barend du Plessis, Minister of Finance, Pretoria

The history and structure of the gold-mining industry in South Africa
Mr Willi Malan, Anglovaal, Johannesburg

Gold: its time and its place
Professor D.A. Pretorius, University of the Witwatersrand, Johannesburg

Development of gold-mining technology—past, present, and future
Professor Miklós Salamon, Colorado School of Mines, U.S.A.

Industrial relations and labour developments in South Africa
Professor Nic Wiehahn, School of Business Leadership (UNISA), Pretoria

Gold in the international monetary system
Professor Antal Fekete, Memorial University of Newfoundland, Canada

The extractive metallurgy of gold
Mr Jack Holmes, Anglo American Corporation, Johannesburg

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Recent research results relating to the industrial uses of gold
Dr Geoff Gafner, Intergold, Johannesburg

An overview of the supply and demand for gold
Mr George Milling-Stanley, Consolidated Gold Fields, London

The role of gold in the financial system
Dr Roger M. Gidlow, Economic Adviser, SA Reserve Bank, Pretoria

The Guest Speaker at the Conference Banquet was the State President, The Honourable P.W. Botha. His speech was followed by a vote of thanks on behalf of the overseas delegates by Mr Tom Wolfe, a consultant from Washington D.C.

Tony Hudson of SABC-TV interviewing Mr Barend du Plessis, Minister of Finance, who presented one of the plenary addresses at GOLD 100

Gold-mining Technology

Valuation and Gold Distribution

Speakers in this session emphasized that the accurate prediction of gold grades in ore is a difficult but increasingly essential requirement of deep gold-mining operations. Other points of interest that were raised are summarized below.

Growing attention in South Africa is being directed towards the creation of structural models for gold values in deep gold mines, and towards an understanding of gold-distribution patterns since the gold on the Witwatersrand was laid down at the edge of ancient lakes.

Grade-valuation problems for deep-level gold mines fall into two categories: those encountered in exploration and feasibility studies for virgin properties, and those encountered in producing mines. In exploration, the cost of drilling additional deep boreholes, the limitations of selective mining to a pay limit at depth, and the high variability of the gold values throughout an orebody are factors calling for a more fundamental understanding of the nature of gold deposition and occurrence. In producing mines, there is a need for meaningful geological and geostatistical interpretation of the basic structural patterns to give mine managements adequate information for effective mine planning and ore-reserve valuation, and to enable them to mine in selective areas and to control variations in grade.

The average grades and variations in grade remain the most sensitive influences on the financial return from Witwatersrand gold mines. Studies of the particle structure of the alluvially formed reefs of the Witwatersrand, known as sedimentology, are aiding valuation estimation in two ways. Firstly, sedimentological principles can be used in the modification of geostatistically built models since they allow individual evaluation of separate sedimentological regions. Secondly, they can aid a deterministic approach that generates a model by mathematical means.

Accordingly, it has been possible to develop a good relationship between the sedimentary characteristics of deposits in the Witwatersrand System and the concentration distributions found within them. While such theoretical advances in valuation are under way, the physical sampling of ore, which is required in the making of short-term decisions in regard to panels (parts of a stope) and scale mining, is hampered by the need for the large number of samples that would allow for the erratic nature of the gold grades on the Witwatersrand.

Manpower limitations do not readily allow such intensive sampling, and the development of a portable gold analyser is expected to alleviate this problem. Now at an advanced stage, this lightweight instrument for one-man operation uses energy-dispersive X-ray-fluorescence principles for the determination of gold and other elements.

A fundamental advantage over conventional chip sampling is that the machine gives an immediate readout of gold grade at the stope face, enabling the operator to gain a much more rapid conception of grade patterns in a stope area than is available from conventional chemical analyses.

The delineation of geologically similar parts of an orebody is an essential prerequisite for the application of the geostatistical techniques of grade evaluation. Where this is difficult, geochemical methods can now be used to differentiate between different geological elements (facies). This allows the construction of better models of the formation of individual goldfields.

Another crucial aspect of sampling is the precise grade of the ore being delivered to the surface metallurgical plant. Substantial progress has been made in this problematical field, enabling estimates to be made of the gold 'lock-up' that occurs in run-of-mine mills and of the efficiency of underground operations by a comparison of underground ore-survey grades with the head grades of

the ore delivered to the reduction plant.

Stoping Technology

Virtually every advance in mining know-how is ultimately intended to enhance production performance in the working stopes where the gold ore is mined. The improvement of working methods within the stopes themselves, particularly by the use of advances in stoping technology, is receiving much attention. One of the presentations gave an introduction to the objectives, restrictions, and priority areas in the development of stope machinery for deep gold mining.

Inevitably, mining is moving towards a higher degree of mechanization, a trend that is growing in importance because of the demands of the still-greater mining depths that are envisaged for tomorrow. The fact that the development of stope equipment is generally slow is attributable to the harshness of the working environment, which makes unique demands on both men and machinery. The introduction of new techniques also inevitably invites resistance to change, incurs high costs, and usually results in initial unreliability.

Nevertheless, the industry has identified a number of priority areas to spearhead tomorrow's technology, which include the control of rock pressure; the application of hydropower; the development of components to create really mine-worthy machinery; the development of abrasion- and corrosion-resistant materials; the designing of more-reliable units devoid of power-conversion systems and of components such as screwthreads and others incorporating a minimum of moving parts; and, finally, the development of mining methods without explosives.

One phenomenon dictating the design parameters of mechanical mining systems is the unpredictable and varied effect of geological features and rock fracturing at depth. Machinery must be designed with the necessary articulation and flexibility to negotiate geological disturbances, fractures, joints, and other local geological structures that hinder consistent mining. Rock-breaking systems that rely on a degree of fragmentation in the working face ahead of mining (caused by a concentration of rock-pressure effects) have shown the greatest promise for the mechanization of deep-level gold mines. Such impact breakers or ripping machines have now been shown to be the most attractive means of mining without explosives. Although they are capable of achieving adequate production rates, they require effective complementary rock-handling equipment and reliable components. Practical development continues.

One other concept associated with the development of stope equipment is the powering of all stope machinery by the hydrostatic pressure gained by the chilled water as it is sent down into a mine for cooling purposes. Such water is carried underground by water columns running down the sides of the shafts. It appears that hydropower is a safe, reliable, and cost-effective means of increasing stope productivity through the use of water-powered hydraulic equipment for rock drilling prior to blasting, rock handling, and roof support.

Two case histories concluded the session on stoping technology. One dealt with the unfavourable mining conditions in the highly stressed 3M area of President Brand Gold Mine, and the other with mining without permanent roof support in mined-out back areas in parts of the Hartebeestfontein Gold Mine.

The Underground Environment

The mining of gold at depth in South Africa presents environmental problems caused by heat, ventilation dust, gases, noise, and illumination, which to date have been met and overcome by the extensive resources of bodies such as the Chamber's Research Organization and those of the mining houses and individual mines. An overview of these problems identifying major steps forward and outlining continuing research opened this session.

Because rock temperatures are higher at deeper levels than near the surface, the rate of heat emission into deep mining excavations, and so into the underground atmosphere, is also greater. Heat is therefore a major environmental problem in deep gold mines.

There are four approaches to the heat problem in the mines. The most important is to minimize the heat load placed into the underground atmosphere. Heat caused by mining machinery can be reduced by more judicious design, siting, and choice of energy sources. To reduce the heat flow from rock, the rock surfaces can be insulated, worked-out areas can be closed off, and backfill technology, which concerns the return of ground waste materials into empty stopes, can be used to seal off old footwall and hangingwall surfaces, which emit heat.

The design of mine layouts to reduce heat flow is an involved process, but promising developments have been made in computer-based methods, and insulation and backfill techniques are receiving concerted attention. The design of ventilation and cooling systems is also complex. Generally, the provision of sufficient ventilation air and cooling media is used to solve the problem. Air cooling is used extensively, and chilled water can be used directly for cooling, as underground machine service water, or to bulk cool air. The recirculation of underground air is also receiving attention, since it offers many advantages for deep mines.

Many financial and technical factors are involved in the reduction of mine temperatures to a point, say, where there is no longer any need for the mineworkers to be acclimatized to enhance their heat tolerance. The introduction of greater refrigeration capacity—about 50 per cent more capacity than at present to eliminate all need for acclimatization—depends upon the development of a new generation of mine-cooling technology, which the South African gold-mining industry is pursuing as a high priority.

The direct use of ice to reduce the temperature of underground service water in a mine is a comparatively new concept. A 1000 t/d ice plant was put into effect at the Merriespruit section of the Harmony Gold Mine in November 1985. Irregularly shaped ice particles are piped 1088 metres underground to provide improved cooling in a mine that suffers from the incursion of a large amount of hot fissure water from rocks. Studies have shown that substantial advantages can be expected from ice cooling in ultra-deep gold mines because of the greatly reduced pumping costs. It has yet to be determined whether the pneumatic conveyance of ice horizontally underground, or the pumping of ice as a slurry, is the most practical means of using the cooling property of ice

particles to lower the temperature of service water in remote locations underground.

The final part of the session was devoted to energy-saving ways to pump warm, dirty mine water back to the surface. Large savings in energy can be made by the use of the pressure head gained by the cooling materials piped underground to drive conventional motors and pumps. Work is in hand on a far more efficient system of utilizing the hydrostatic head of descending ice slurry or chilled water. This system lifts warm, dirty water back to the surface in a complex U-tube arrangement. Such a system, as perfected at the Hansa Mine in West Germany, was also able to hydraulically hoist to the surface 5000 tons per day of raw coal that had been introduced into the water system. It may be possible for gold concentrates from South African gold mines to be raised in a similar way.

Rock Pressure

This session opened with a review of the extensive ramifications of extremely high rock pressure in deep gold mining. The thin, tabular nature of orebodies at depth results in very high rock pressures, which cause extensive rock fracturing and can lead to violent rock failure known as rockbursts. Rockbursts and rockfalls are responsible for more than half of all the fatalities and a quarter of all the injuries in gold mining. Unfavourable rock conditions resulting from poor geology and rock pressure can cut underground labour productivity by as much as 30 per cent.

Control of the closure rate in stoped-out areas is an important design aspect of deep-level mining, and can be achieved by the leaving of regularly spaced pillars in mined-out areas, by the backfilling of mined-out stopes with waste rock or slimes, or by a combination of pillars and backfill. Supports in deep-level mines also need to have an initial stiffness to support fractured rock, but then also display the ability to accommodate sizeable rock movements and deformations without being overstressed.

While significant progress has been made in the understanding of rock-pressure phenomena, the subject remains of major concern. Although static pressure problems have now been virtually overcome, dynamic pressure problems, including rockbursts, still retain a considerable element of uncertainty.

One approach to the rock-stress problem involves the construction of numerical models for use in practical mine design. This approach is possible because of the unusually homogeneous and competent nature of the host rock in South African gold mines. One such model is the MINSIM-D program, which is a tabular stress analyser capable of modelling three-dimensional multi-reef mining configurations. It is used to assist in the siting of haulages and other excavations, the sequencing and layout of stopes to minimize energy release rates, the layout of barrier pillars or backfill systems, the design of shaft or boundary pillars, and other problems in which the laws of elasticity can be applied to the rock mass.

Ways are being developed for the modelling of inelastic phenomena such as the failure of abutments or pillars, the mode of support in blocky fractured ground, the detailed compaction of backfill, and the rupturing of rock mass.

Attention is also being given to the quality of backfill materials, and to the selection of materials to give optimal performance in different underground situations. The quality of the fill is very important in the creation of effective ground control. Quality can be determined by such factors as porosity (the space between particles), water content, deformation under load, pumpability, and even heat-conducting qualities.

Backfilling is attributed with many advantageous characteristics including improved regional support, support of workings in multi-reef mining (where reefs are mined one above the other with limited intervals between them), control of the potential movement of particular geological strata, and environmental control where ventilation air is prevented from passing through worked-out areas, in which it picks up unwanted heat, rather than being channelled along working faces. Backfilling is also attributed with benefits in retarding the progress of underground fires, or even eliminating such fires. However, when waste rock is used as a backfill material, the hoisting requirement of a mine is diminished.

The materials currently used as backfill fall into two broad categories: metallurgical-plant tailings, and crushed and milled waste rock. Combinations of the two are known as tailings–aggregate mixtures. Fill materials derived from metallurgical-plant tailings are prepared by a variety of filtering and dewatering processes, which alter their size distribution and therefore their physical characteristics. Cementitious materials can be added to further improve their properties when placed in a mine. Although there are several instances where waste material is hand-packed underground, there is only one instance where hydraulically placed fill is prepared underground from waste. Tailings–aggregate mixes are not currently being used as fill but offer attractive possibilities, including more desirable qualities than either of their individual constituents.

The properties sought from backfill relate to its aptitude for support, placement, pumping, and heat conductivity. Most of these properties derive from how the fill particles pack together when placed underground. This particle packing density is known as porosity, and depends primarily on the amount of water present when the material is placed and also on the rate of drainage or dewatering. Work is in hand on the determination of the minimum porosity at which each material can settle, and this determines the final characteristics of the fill. Naturally, more water than is equivalent to the minimum porosity is needed when the fill material is piped into place underground, but subsequently dewatering takes place over hours, weeks, or months, depending on the type of material. During this time, the porosity drops.

The rate at which various materials dewater affects their performance *in situ*; the addition of from 3 to 10 per cent by mass of cement additives can considerably alter dewatering effects, which are manifest in phenomena such as shrinkage of fill and loss of fine material with the departing water. Further work on the performance of various fill materials under different mining conditions has shown the suitability of various materials for different backfill tasks where they experience varying degrees of stress.

A presentation on backfilling by the Gold Fields group

Mr D.W. Steyn, Minister of Mineral and Energy Affairs, about to strike the first medallion at Gold Reef City on 3rd September, 1986

The 1-ounce gold medallion, consisting of 999,9 parts of gold per thousand, that was struck by the South African Mint to commemorate the discovery of the Witwatersrand goldfields a hundred years ago

concluded that, as a major breakthrough for the mining of narrow tabular orebodies at depth, backfill will affect virtually every mining operation from the surface to the stope face. The use of stabilizing pillars, so far necessary to assure rock stability in deep mining but a cause of ore reserve lock-up, could be dispensed with down to a depth of 3500 metres as a result of the use of backfill.

A further paper presented to the session broadly analysed the benefits, drawbacks, and application of all forms of stope support, and concluded that stope support is still very much more of an art than a science.

The session also included a description of the design and widespread use of crush pillars to combat geological bedding-place separation on Cooke 2 shaft of the Randfontein Estates Gold Mining Company. Crush pillars are intended ultimately to fail but, in so doing, to decrease the rate of rock convergence and energy release of the closing stope roof.

New Developments in Gold Mining

The final mining session concerned new developments in gold-mining technology. The following were confirmed as issues of paramount future importance: strata control; thermal control; the efficient movement of men, rock, and materials; valuation techniques; and faster rates of advance to lower costs. The greatest priority was placed on the efficient movement of men, materials, and ore.

A reduction in the amount of barren rock transported, hoisted, and processed on surface offers cost-cutting opportunities. However, innovative ideas are necessary if hand sorting is to be replaced as a means of separating ore from waste; to date photometric, radiometric, and infrared identification systems have been investigated. Backfilling and better reef evaluation offer opportunities for reducing the over-breaking of rock and for conducting more selective mining to improve the exploitation of local grade values.

Further presentations described the practical application of a modern, computerized valuation system for the strategic management of low-grade Witwatersrand gold

mines, a review of recent research findings into the dynamic behaviour of the steelwork in an operating shaft, and the mid-shaft loading system at Cooke 3 shaft, Randfontein Estates Gold Mine, which allowed primary development on the 106 level to proceed concurrently with sinking operations in the shaft.

The Extractive Metallurgy of Gold

Plant Design

The growing use of carbon-in-pulp for the extraction of gold was clearly illustrated at the opening of this session, with an account of the new gold plant at President Brand. Commissioning of the plant began this year, and it replaces a conventional plant including crushing, pebble milling, filtration, and clarification/zinc precipitation with a plant including run-of-mine milling, leaching, carbon-in-pulp, elution, and zinc precipitation. The feasibility studies, pilot-plant testwork, process route and equipment selection, design, construction, and capital costs were described in detail.

This presentation was followed by an account of a project to increase milling capacity at Harmony Gold Mine. Lower capital expenditure, favourable operating costs, and relative ease of expansion were decisive factors in the selection of run-of-mine milling at the Mine. Salient features of the four mills chosen—two at the Virginia section of the Mine and two at the new Central Plant—were outlined.

Carbon-in-pulp and resin-in-pulp extraction depends upon the interaction and contact between materials carried in counter-flowing currents through a series of mixing vessels or 'contactors'. The contactors now developed permit a high throughput of pulp in the gold-recovery stages, with high concentrations of carbon or resin. This allows the contactors to be smaller by 80 per cent than a conventional adsorption plant. This reduces the capital costs by up to 45 per cent; the operation is very much simpler, and the operating costs are also significantly less. Although no plants of this design are in operation as yet, two commercial plants are being designed and will be installed in 1987.

Heap-leaching cyanidation technology came to commercial fruition in the U.S.A. in the 1970s, but lower-grade deposits of oxidized, disseminated ore are not amenable to conventional heap-leaching technology. The process of agglomeration pretreatment has been developed to overcome this and is now in commercial use.

The session concluded with an account of the heap leaching of submarginal-grade ore at Masbate Mine in the Philippines: leaching is carried out on ore with a gold grade of 1 g/t at a rate of 1250 t/d in an area where the rains average 40 cm per month.

Carbon-in-Pulp

A detailed study of the adsorption of gold cyanide onto activated carbon and the establishment of the parameters affecting plant behaviour has identified the principal factors influencing the efficiency of a carbon-in-pulp circuit.

Research resulted in the design of the Linear Screen, which is capable of efficiently screening mineral pulps at any size between 200 and 1000 μm. This machine has already proved itself in removing tramp oversize material from the cyclone overflow, thickener underflow, and sand-plant feed, in scavenging carbon, and in separating resins from pulps. The replacement of conventional vibrating screens by Linear Screens in several gold plants is testimony of the machine's acceptability; 59 units were ordered within 18 months of the commissioning of the first prototype. Details of the background, design, and early commissioning were presented.

Mr G.Y. Nisbet, Chairman of the Planning Committee, welcoming the guests to the Johannesburg zoo on the evening of 'Food from Africa'

Studies of the factors affecting the elution rate of aurocyanide from activated carbon have led to the evolution of a model describing the kinetics of elution. In another study, that into the kinetics and activity of carbon samples exposed to a range of trace organic chemicals commonly found in carbon-in-pulp plant feeds, the degree of fouling and deactivation that carbon may undergo over an extended period of plant use was assessed.

Eluted carbon requires periodic regeneration for it to recover and retain its adsorption affinity for aurocyanide in a carbon-in-pulp plant, and a novel regeneration process has been developed. A voltage is applied across dry granular activated carbon, and rapid heating is achieved; in this manner, even heavily contaminated carbon or lower-grade carbon can be activated. The process has required the development of a resistive-heating Rintoul furnace; its inception, development to pilot scale, and effectiveness were outlined.

Studies into the electrochemical reactions involved in the cementation of gold onto zinc from concentrated aurocyanide electrolytes were also described.

Micron Alcohol Desorption is a relatively new method for the rapid recovery of gold from activated carbon at

low cost, and the production of stripped carbon ready for immediate re-use in the carbon-in-pulp circuit. Because the gold-bearing liquors resulting from elution are of a very high grade, novel recovery methods can be used.

A further presentation introduced an automated instrument for determining the activity of reactivated carbon. Subsequently, an account was given of the work leading to the design of agitators at the ERGO carbon-in-leach plant; ERGO uses carbon-in-leach, an adaptation of the carbon-in-pulp principle, to reprocess low-grade material from mine dumps on the East Rand.

Finally, a description was given of the derivation of metallurgical data on the effects of free cyanide concentration and pH value on gold adsorption in the carbon-in-pulp process. These are the two factors most critical to optimal operation.

Refractory Gold

This session started with a presentation on the factors affecting the treatment of refractory gold ores (ores in which gold is locked in various host minerals, no two of which are identical). An assessment was given of how technology can cope with interactive factors to provide the best technical and cost-effective treatment routes. There followed accounts of the mineralogical changes that occur during the roasting of arsenical gold concentrates, and also of recent work on the recovery of gold from refractory gold-bearing ores and on techniques for enhancing their susceptibility to the cyanidation process.

Pressure oxidation is a technique that can now render difficult sulphidic ores amenable to cyanidation; modelling of the mechanism of sulphide oxidation and the release of gold during the bacterial leaching of ores gives an insight into this form of gold-recovery process.

Unconventional Techniques

Under appropriate conditions, both gold and uranium can be dissolved and recovered simultaneously from gold-and-uranium ores; both metals are extracted from the leach liquor with anion-exchange resins. Important to the mining industry is detailed knowledge of these resins, which may lead to the development of a commercial resin specifically for the recovery of gold from cyanide liquors, with advantages over carbon adsorption. Both lines of research were presented during this session.

A review of advances and established procedures in the carbon-in-pulp recovery of gold at the Western Areas Gold Mine summarized developments in the five years since the plant at the Mine was commissioned as the largest in the industry, in November 1980.

Work over two years on the development of a biological leaching process for the treatment of sulphidic gold and silver concentrates by Giant Bay Biotech has led to plans to build a commercial plant in Canada.

Acids originating from vegetable matter on the mine dumps that are being reprocessed by Rand Mines Milling & Mining in Johannesburg have fouled the carbon used in the carbon-in-pulp process; the problem and its solutions were outlined.

A fully automated instrument for the analysis of gold ores as a replacement for the existing fire-assay method was described. Known as the Aztec instrument and using an X-ray-fluorescence technique, it is sensitive to 0,5 parts of gold per million.

Other fields of development that were presented included a biological process for the treatment of gold-mining effluents, milling in a ceramic ball mill prior to cyanidation for improved recovery from gold-bearing calcine and pyrites, and the benefits of wet high-intensity magnetic separation in the treatment of gold-bearing residues.

The analytical methods presented included applications of nuclear technology in gold-extraction metallurgy, where radio-isotopes form the basis of a variety of measuring and investigative techniques; spectroscopic methods for the investigation of the chemistry of certain gold ores; and various gold and silver assaying methods.

Grinding and Concentration

One presentation pointed out that increased throughput and power savings can be achieved in the milling of ore if the pebbles of a certain size that are largely barren are removed from the mill feed. During such sorting, some 80 per cent of the ore can be discarded.

Impactive and abrasive effects within a ball mill were shown to vary with ball size distribution. Impact forces also depend on the speed of rotation, diameter, and lining design of the mill. The load within a mill and the density of the mill pulp can be determined by the novel use of microphones, and this information can be used in such a way as to result in better control of the power consumption.

Other presentations, dealing with grinding and ore concentration, described the influences of various chemical, physical, and mineralogical factors in the flotation of gold-bearing pyrites. Investigations into the effects of flotation parameters on the flotation behaviour of the pyrite, gold, and uranium contained in Witwatersrand-type ores, and into the development of a radiotracer technique for the evaluation of gold recovery by gravity concentration were also outlined.

The Industrial Uses of Gold

Industrial consumption represents a very significant portion of gold demand, particularly in the fields of electronics, dentistry, and jewellery. The development of alloys is a fundamental key to the expansion of this industrial use of the metal, and the vital need for critically evaluated data in the form of phase diagrams was highlighted.

Phase diagrams are crucial to an understanding of the relationships between alloy structures and their engineering properties; consideration was given to an internationally co-ordinated programme to collect and critically evaluate the available data. It was announced that the programmes in respect of gold-containing binary and ternary systems had been completed, and that monographs on these systems were being prepared. The role of Intergold's Technical Information Service for gold users, which keeps abreast of current technical and scientific literature by continuously monitoring the gold-related patent and non-patent literature, was also outlined.

A session on electrochemistry reviewed advances in the electrodeposition of gold and gold alloys to create deposits with properties and colours suitable for use in both decoration and electronics. The new techniques of

high-speed selective plating, pulse plating, and laser-enhanced plating were described.

In a discussion of South Africa's jewellery-fabrication industry, which is small in relation to the country's resources of precious metals and diamonds, it was suggested that the industry might be expanded by the use of electroforming to produce items of gold jewellery. The view was expressed that the production of 'limited edition' jewellery could be developed on this basis, with a distinctly Southern African flavour.

In work that had been carried out on certain gold alloys used in dentistry, an assessment was made of their susceptibility to corrosion and tarnishing in artificial saliva. It was concluded that the corrosion resistance of the alloys is closely linked to their degree of nobility, i.e. their content of noble metals. Below a nobility of 33 per cent by atomic mass, there was a sharp drop in corrosion resistance.

A paper from Japan dealt with the production and application of fine gold wire in electronic devices. Such wires are widely used in the construction of transistors and integrated circuits. New miniature packages, such as chip-carriers, continue to demand gold wire of new levels of quality and reliability. Fine gold wire remains a critical element in semi-conductor assembly. For cost reasons, wire is being called for in greater lengths per roll and with still-smaller diameters. The techniques used to control the production of wires conforming to these requirements were discussed.

In a paper from the Research Institute for Precious Metals and Metal Chemistry in West Germany, three examples of developments in alloys for gold jewellery were presented: the improvement of casting alloys, the development of 14- and 18-carat gold alloys with improved deformation characteristics, and the development of an alloy with a gold content of 99 per cent and properties at least equal to those of the lower-caratage alloys in use today. Such an alloy permits the production of gold jewellery and coins of caratages in excess of 23.

The future of the use of gold and gold alloys in dentistry was critically reviewed in the light of rising gold prices and the increasing availability of alternative materials. Although the alternative materials do not have all the advantageous attributes of gold and gold alloys, they will replace gold to an increasing extent unless more attention is given to the development of new gold-based materials and of techniques of using them.

A review was presented of trends in the organic and organometallic chemistry of gold. Single-cyrstal X-ray diffraction and other techniques have made it routinely possible to determine the structure of materials and categorize them in relation to their properties. Such materials include compounds for epitaxy and surface coatings, drugs for gold therapy, substrates for the preparation of catalysts, and precursors to colloids and pigments. A significant recent development has been the recognition that, among the chemical elements, relativistic effects are at a high peak in gold, i.e. the atomic structure of gold is such that the metal displays more unique properties than ever realized before. This was elaborated upon, and the way in which this phenomenon explains many of the special features of gold and its compounds was described.

In a final paper, significant features of the development of the use of gold in medicine and dentistry were also outlined in connection with future consumption trends for the metal.

The Economics and Marketing of Gold

With the gold price rising to above $400 at the end of August, a feeling of optimism prevailed during the four days of the Conference. The general consensus was that the economic climate favoured a stable rise in the gold price in the months to come. Bullion dealers from the U.S.A., Switzerland, and Hong Kong were unanimous in their outlook for the price in the short term, predicting a range of between $400 and $500.

The Demand for Gold

The main demand factor that was repeatedly stressed by delegates was the extraordinary Japanese demand for gold. According to Mr A. Imamura of the Sumitomo Corporation, this demand will remain strong for the following reasons: increasing private hoarding, the growing popularity of gold jewellery, and the potential demand for other gold coins like the American Eagle and the Australian Nugget. Gold is being actively promoted in Japan, attitudes towards it are changing, and it is being accepted more as a hedging asset, while other investments are losing their attractiveness (because of low interest rates, etc.). Imports of gold jewellery to Japan are also booming since the import duties have been reduced, the yen gold price has been falling steadily, and the demand for gold jewellery is for both asset and consumption purposes. The success of the Hirohito coin could result in further issues, and hence additional gold imports.

Gold jewellery takes up about 65 per cent of the newly mined gold in the world. According to Mr F. Torboli of Intergold, Geneva, the total fabrication is at about the same level as it was fifteen years ago, but the industry has undergone a number of important changes. These include the introduction of new production technology that has resulted in the more cost-effective production of gold jewellery, and in a decrease in overall manpower and number of manufacturing concerns. The gold-jewellery industry is becoming increasingly marketing-oriented with greater product variety and flexibility and more aggressive promotion. Important shifts have also occurred in the location of the manufacturing concerns, with traditional suppliers such as Europe having lost its market share to manufacturers in the Far and Middle East.

The industrial demand for gold is an important but stable component of the overall demand (about 17 per cent). This gold is used for electrical equipment and electronics, for dental applications, and for other industrial purposes (such as decorative items, photochemical uses, catalysts in the chemical industry, laboratory equipment, medical applications).

Mr U. Seiler of the Union Bank of Switzerland discussed two main factors that determine the industrial demand for gold. Firstly, the rate of real growth of an economy is important, since an increase in the real GNP growth rate usually results in an increase in most components of industrial demand. Secondly, a strong gold price or expected future rise will tend to lower industrial demand, although this effect on demand is neither direct nor

substantial. It is also important to remember in what currency the gold is being valued.

Given the current world economic outlook of an expansionary monetary policy, lower growth, and possible increase in inflation rates, delegates were generally optimistic about a rising investment demand for gold. Investor portfolios are being altered in favour of gold and gold-related investments. In a sense, this component of aggregate gold demand depends on opposing factors that influence industrial demand; that is, a sluggish world economy and an expected increase in the price of gold are both bullish factors for investment demand.

The Supply of Gold

The exploration for new gold deposits and the development of existing gold mines in the U.S.A. and Canada have accelerated significantly over the past few years. In Canada, mineral exploration has been encouraged by allowing a private or corporate investor to write off investments in mineral exploration against other income.

According to Mr P. Warrington of Noranda Sales Corporation, gold-mine exploration and development have increased in the U.S.A. because of the following factors: improved heap-leaching technology (pressurized oxidation, improved cyanidation treatments, and carbon-in-pulp extraction), making previously uneconomic reserves now profitable; other base metals are not cost competitive, and only gold prospects are optimistic; some innovative financing methods have appealed to investors and speculators; investment in North American gold mines allows investors to diversify and reduce their South African exposure; and the existence of skilled labour facilitates expansion. The average costs are around $220 per ounce, and are expected to remain at current levels or decline slightly, given that a number of economic heap-leaching operations will be coming on stream.

Mr Warrington expected gold production in Canada to rise from 85,5 t in 1985 to 124,3 t in 1990, and in the U.S.A. from 73,7 t to 129,2 t. This will mean that North America will produce about 18 per cent of the Western World's primary production by 1990, in terms of his estimate of 1410 t for the total production of the Free World.

Looking mainly at Brazil, Australia, and Papua New Guinea, Mr D. Morley of the Western Mining Corporation expected gold production to remain strong and increase in the coming years, since cost-price relationships —particularly due to favourable exchange rate movements—encourage the exploitation of many existing and recently discovered reserves.

In the past fifteen years, the 'garimpeiros' production in Brazil has been the main reason for the rising production. Also, the investment climate in Brazil is favourable for increased gold production, and there has been considerable interest from foreign mining companies in exploration. The potential for new major gold discoveries in Brazil is excellent according to Mr Morley, since many areas are largely unexploited. He suggested that productions of 80 to 100 t in the 1990s should be expected.

Gold production in Australia has been increasing over the past five years—from 17 t in 1980 to 57 t in 1985. Mr Morley gave the following reasons for this trend: the increased real gold price in Australian dollars; a favourable tax regime for gold mines (income earned from the working of mining properties for the recovery of gold is exempt from income tax); limited State interference; mostly open-cut operations with relatively low operating costs; improved techniques.

Russian production was perhaps the most contentious subject on the supply side during the Conference, with estimated supplies to the West varying from 210 to 300 t/a. The fall in energy prices in 1986 suggest that the Soviet Union will need to sell considerably more gold this year than it did last year to generate foreign-exchange earnings.

Although the supply of gold from the Free World is expected to increase from the current annual rate of 1220 to 1440 t/a over the next five years, demand from the East and the introduction of numerous gold coins worldwide will offset this boom in supply.

It was generally agreed that the higher gold output by other countries will reduce South Africa's share of world output in the next few years.

Gold-mining Shares

The view that gold is currently in a bullish phase was also put forward by Mr J. Baring of James Capel & Co. He believed that the increasing U.S. trade deficit, the falling dollar, steadier oil prices, weaker bond markets, and the possibility of higher inflation are the main factors behind the recent strengthening of the gold price.

He believed however that 'the party could be short but sweet', since he estimated that the supply of gold would exceed the demand by over 100 t in 1987—although this surplus could be absorbed by investors if the investment climate is favourable. The FTS Gold Mines Index has been on a declining trend for the past 24 months, but there has been a recovery from the July low.

Mr Baring also pointed out that there could be a one-off special demand for about 200 t of gold early in 1987, given the fact that the French government issued a bond in 1973, which, under certain conditions, could become gold-linked and is now due for repayment.

Another speaker, Mr W. Floquet of Martin & Co., also stressed the increasing gold production worldwide. He believed that technological improvements in geological-survey techniques (including the use of satellite surveys, magnetic imaging, and vibroseis equipment) are all making gold easier and less costly to find. In addition, many mining companies that previously concentrated on base metals are increasingly turning their attention to gold mining.

Mr Floquet emphasized the need to actively manage a gold-share portfolio that takes the following into account: mine life, grade, costs, growth potential, current yield, and life-of-mine internal rate of return. Concluding on a positive note, he said that South African gold-mining shares offer significant value, although volatility must be expected.

According to Mr Van Eck of International Investors Inc., the U.S. fund industry has witnessed explosive growth over the past few years. The main types of funds are money-market funds, short-term municipal-bond funds, income funds, and equity funds (under which gold funds are classified).

The total assets of gold mutual funds in 1979 were $300

million, while in March 1986 they came to $1,6 billion, although this is only 1,6 per cent of the total market. He estimated 50 per cent of the total gold-oriented funds to be in South Africa. He believed that the gold price is on an upward trend, mainly because of the renewed investment demand, which is based on financial uncertainty.

Dr R. Gidlow, looking at the changing world financial system and changes in the structure of banking, discussed a number of potential implications that these could have for gold. The international banking system has undergone a revolution, with many innovations. There has been a pronounced shift from traditional bank lending to securitization markets (i.e. borrowers are now raising funds by issuing marketable securities, which have back-up facilities from banks). At the same time, a number of new financial instruments have come onto the market (forward rate agreements, currency swaps, interest rate swaps, etc.) amidst the deregulation of financial markets and increasing competition between market participants. These developments have been very constructive from the point of view of both investors and borrowers, but he believed problems could arise over the stability of the financial system (because of excess borrowing and less control), and hence gold could benefit from increased instability.

In addition, financial liberalization in world markets will have both a negative and positive influence on gold. Deregulation, by allowing a whole spectrum of new investment facilities, could divert some money away from gold. On the other hand, the restrictions on gold transactions will also be relaxed or abolished, given liberalization of markets, and hence an expanding market for gold could result. The numerous new gold-coin issues in the near future should also stimulate the interest in gold.

The Marketing of Gold

Mr Chick Hood disclosed that Intergold has devised a new sales strategy to absorb the expected gold surplus of the next five years. The tactics being adopted include an extensive international promotion of gold jewellery through the use of television and the exploitation of overseas gold-coin launches.

According to Mr Winfried Kilp of Intergold in Geneva, the launching of the new coins will stimulate the demand for gold at times of rising gold output in the world. In the U.S.A., the gold Eagle is being reminted, and the U.S. Treasury is likely to capture 50 per cent of the U.S. gold-coin market with sales of Eagles. The Luxembourg Lion has been launched in anticipation of increasing political boycotts against the Krugerrand in Germany, Switzerland, and the Benelux.

Dr Louw Alberts, Director General, Mineral and Energy Affairs, examined the reasons why South Africa has never beneficiated its gold beyond the ingot stage prior to export, despite the fact that the value of the gold content of jewellery, thin wires, alloys, and sheets is increased by as much as 1000 per cent. Pointing out that the South African government's overall policy towards the mining industry has always been one of the best in the world, he said there is considerable room for improvement in regard to the deregulation of the heavy taxation that has hampered entrepreneurs who want to enter the field of gold-jewellery manufacture. Dr Alberts also pointed out that an industry as big and powerful as the South African gold-mining industry has shown a strong tendency in the past to view the mining and extraction of minerals as an industry separate from the industry manufacturing primary products into artifacts. He considered that this approach has given rise to a tremendous inertia in the mining sector when it comes to added-value ventures.

Dr Alberts also made the point that the highly respected and successful organization Intergold has mainly promoted gold and its applications in a general international sense, the argument rightly being that, if more gold is used worldwide, South Africa, as a major producer, can only benefit thereby. However, no serious prolonged attempt has been made to foster centres of excellence in research and development on gold and its uses within South Africa or to transfer added-value technology *per se* to South African participants. He ended by suggesting that, of all the great financial institutions in the country, the gold-mining industry should take the lead in adding value to gold to the ultimate benefit of all the peoples of South Africa.

According to Mrs Paula Janeke, University of South Africa, gold's marketing potential rests mainly with the impact the yellow metal has on the human psyche. A survey by Intergold conducted in Europe and the U.S.A. on the changing perceptions and attitudes towards gold jewellery showed that the human regard for gold has changed very little over the years. On being questioned about their reasons for wearing gold jewellery, women generally emphasized gold's warm lustrous colour, its durability, its standing as a symbol of love, its versatility, and the high value of real gold jewellery.

The Gold Market

Mr Kenneth B.K. Yeung of King Fook Finance Company in Hong Kong stressed the importance of bullion dealers in developing new trading areas that help shape today's gold markets.

Trading innovations result in gold dealings in the global market with a turnover many times that of the world's annual gold production. Consumers who are essential industrial users and private investors have always been on the lookout for economical ways of buying and selling gold. The dealer's role is to design techniques that will minimize risk and maximize profit. Among the techniques offered by dealers are gold fixings, continuity in price quoting, regulation of the gold price, hedging in gold, options, and bullion banking. Bullion banking is a relatively new concept. It stems from the gold consignment or leasing business, and enables investors to add liquidity to the market. He believed that the liquidity and efficiency from the burgeoning market confirm that gold is a liquid asset and not a mere commodity.

Mr Stanley Au from Hong Kong also emphasized that 24-hour gold trading will be reinforced by a new generation of market operators and by some regional markets. He believed that South Africa, as the world's largest gold producer, should allow its banking system to deal in physical gold. This could lead to South African bankers becoming active market-makers and thereby reduce its dependence on London, Zurich, and New York. If the Reserve Bank offered gold swaps to smaller gold dealers,

it could improve liquidity in the international gold market. Gold trading spread among too many futures markets will only dilute liquidity. Experience has shown that facilities for smaller investors and speculators in the London market are an adequate substitute for the futures market. In recent months, Taiwan has been making increasing use of the Hong Kong market to boost its Forex reserves by gold sales. This new source of physical gold has strengthened Hong Kong's regional importance and emphasized arbitrage opportunities between Hong Kong and other markets.

Mr Paul Sarnoff, director of The Metals Consultancy, reiterated the general view that, although the rise in the physical gold markets has been strong, the growth in the futures market in paper trading as opposed to physical trading has been growing stronger since 1974. He placed greater emphasis on the futures market as precursor to the physical market. Consistent buying in the physical markets like the recent Japanese coin purchases helps attract speculators in futures. Their action filters through to the physical markets.

The Gold Price

On the question of the gold price, Mr Rolf Willi, General Manager and Treasurer of the Dresdner Bank in Frankfurt, presented a very thought-provoking paper on the role of the central banks in the gold markets. Of the 94 000 t of gold dug since the year 5 B.C., no less than one-third has been held by central banks and similar institutions. He noted that there ought to be an international swap network between the IMF and its member countries so that the central banks can mobilize their gold reserves. He believes that more central banks should consider lending part of their holdings to the market 'for the hedging and financing of (gold) producers and users, with the banks and bullion houses acting as intermediaries'.

American consultant Thomas Wolfe, in giving the U.S. perspective on the gold price, did not attach much importance to inflation theories. As a result of the decline in the gold price in the 1980s, and the rise and fall of the silver price, there is a residual attitude that gold is a volatile, high-risk, mainly speculative, investment. His view was that a stronger emphasis on growth by most countries will mean a gradual rise in the gold price, as well as commodity prices in general, for the rest of this decade—probably into the 1990s.

The bankers in Switzerland were also optimistic about the gold price, and were forecasting an average over the next 12 months of more than $400 an ounce. Mr Rolf Schriber, Senior Vice President of Credit Suisse, listed four factors that would decisively influence the markets' performance in the near future. For investors, the main factor is the expected future course of inflation. The gold price's peak of $850 coincided almost exactly with the highest post-war inflation rate. Actually, it reacted more quickly than inflation, since it began to rise when the general rate of inflation in industrial countries was still tending downwards. The correlation between gold and share prices is also important. A take-off of the bull market on Wall Street is usually accompanied by a decline in the gold price and *vice versa*. The platinum-to-gold ratio frequently foreshadows changes of trend in the gold market. The market interdependence resulting from the internationalization of currencies and investment media has been just as effective in supporting the rise of the gold price as it was in accelerating its fall.

Mr Tom Main, Assistant General Manager of the Chamber of Mines of South Africa, emphasized many of the points made by Mr Schriber. Mr Main reported that a study commissioned by Intergold on the influence of political tension on the gold price had found 'no consistent relationship between annual gold price growth and average tension or frequency of high-tension events during the year'.

Mr Robert Sitt, Managing Director of Samuel Montague in Hong Kong, in giving an Eastern perspective on the gold price, told the Conference of the new coin issues coming onto the market: Taiwan is to issue 15 t of gold coins this year to commemorate the centenary of the birth of the late President Chiang Kai Shek; South Korea is producing coins for the 1988 Olympics; China is increasing sales of its Panda coins, with a target of 3 t in 1986; and Australia is about to launch its Nugget coins. These are expected to increase the demand for gold in the Far East. Unless the price increases to speculative levels, the Far East should be able to absorb all South African production. This should 'give encouragement on the downside risk for the price'.

Professor Antal Fekete of Memorial University of Newfoundland, Canada, called for a return to the gold standard and said this could stabilize interest rates at the lowest possible level and enable debt to be extinguished. He stressed that the U.S.A. was responsible for the present predicament of the international monetary system, and only that country could lead the world back to the gold standard. Peter Oppenheimer, Chief Economist of Shell International Petroleum Company, also advocated a return to a gold standard in the international monetary system.

Labour Developments in Gold Mining

The topics covered in this session included industrial relations in the gold-mining industry, the traditional trade unions, the emerging trade unions, the migrant labour system, and future labour developments.

Post-Conference Excursions

One-day excursions were made to the South African Mint in Pretoria, the Stock Exchange in Johannesburg, the East Rand Gold and Uranium Company (ERGO), Simmergo, Mintek, Rand Mines Milling & Mining Company (RM3), East Driefontein Gold Mine, Western Areas Gold Mining Company, and the Rand Refinery.

The extended tour to gold mines in the eastern Transvaal included visits to Fairview, Three Sisters, New Consort, Sheba, and the Consolidated Murchison Mine, as well as a brief stay in the Kruger National Park. Delegates were provided with excursion handbooks containing comprehensive descriptions of the mines and plants visited.

Social Functions and Affiliates' Programme

The social functions arranged during GOLD 100 included a welcoming reception, a banquet, a mayoral braai, and a 'Food from Africa' evening. The highlight was the Conference banquet, which was held at the Carlton Hotel with the State President as Guest of

Honour. The 'Food from Africa' evening, held at the Johannesburg Zoo, was an unusual event, and featured traditional dishes from Southern Africa. As expected, this was an attraction for many of the overseas delegates and proved to be a great success.

The Social Committee arranged a programme principally for the wives of delegates, which consisted mainly of half-day or one-day trips to places of interest such as the SABC, Soweto, and the Oriental Plaza. Two short seminars entitled 'Fascinating Facets of South Africa', held at the Landdrost Hotel, proved to be popular.

GOLD 100 Medallion

A special gold medallion consisting of one ounce of fine gold (999,9 parts of gold per thousand) was commissioned by the organizers of GOLD 100 to commemorate the discovery of the Witwatersrand goldfields a hundred years ago and the centenary of Johannesburg. Only 2500 medallions were minted, which makes the medallion a rare piece for the serious collector with a keen eye for investment potential. The first medallion was struck at the Gold Reef City Mint on 3rd September, 1986, by Mr D.W. Steyn, Minister of Mineral and Energy Affairs. At the time of writing, more than a thousand orders had been received by the South African Mint for the GOLD 100 medallion.

Proceedings of the Conference

The proceedings of the technical sessions, published by The South African Institute of Mining and Metallurgy, were made available to delegates on registration, separate volumes having been printed for the papers on gold-mining technology, the extractive metallurgy of gold, and the industrial uses of gold. At the time of writing, consideration is being given to the publication of the plenary addresses and of the economy and marketing papers in a fourth volume, but this will depend on demand.

Conclusion

The comprehensive nature of GOLD 100, and the quality and diversity of the programme, made it a major success as a forum at which all who are associated with the gold industry could interchange ideas. At the same time, it turned out to be a showcase for South Africa, and will no doubt prove to be a milestone in the history of the South African gold-mining industry.

Mining conference

The Leobener Bergmannstaf (Leoben Mining Conference) 1987 is to be held in Leoben and Graz (Austria) from 22nd to 26th September, 1987. These conferences are held only every twenty-five years, the previous three having been held in Leoben in 1962 and 1937 and in Vienna in 1912. The theme of the Conference is 'Mining: Structural Changes in the Requirements of Economics, Environment and Technology—Tendencies in Research, Development and Operation'. The Conference languages will be German and English.

The topics to be discussed will be as follows:

Mining of Solid Raw Materials

- Prospecting and exploration of deposits
- Deposit evaluation and mineral economics
- Rock mechanics and technology for opening and development
- Basic processes in mining technology and mining machinery
- Underground mining technology
- Open-pit mining technology
- Mineral processing
- Mine surveying
- Mining and the environment
- Mining and the economy

Mining of Hydrocarbons

- Petroleum and natural gas exploitation.

Please refer all questions and comments to

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