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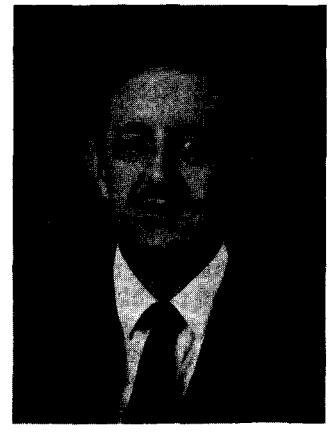
In search of a new development strategy for the beneficiation and export of South Africa's minerals

(Presidential Address)



by H.E. JAMES*

SYNOPSIS

Much has been said and written about the need to reduce South Africa's dependence on gold. To compensate for the decline in the country's foreign-exchange earnings resulting from the phasing out of gold, which must inevitably occur at some future date, a far higher priority will have to be placed on the mining, beneficiation, and export of the 59 other mineral commodities produced in South Africa.

The basic strategy of the mining and metallurgical industries should be to move from the traditional approach of establishing a resource base to the establishment of a market base; to turn from production orientation to market orientation; and to rely less on exploration and economies of scale and more on process innovation and product development.

The enthusiasm, entrepreneurial spirit, and commitment of the leaders in the mining and metallurgical industry will clearly be of decisive importance in the establishment of new industries for the beneficiation and export of added-value mineral-based products.

The State can make a significant contribution by the provision of a well-developed and efficient infrastructure, including rail and harbour facilities, communications and health services, roads, and of electricity and water supplies.

In our search for a new development strategy for the beneficiation and export of South Africa's minerals, we need to recognize that no one nation has all the mineral resources that it needs. Commercial and strategic manipulation of mineral supplies should no longer be tolerated. The future of the human species lies in international cooperation and in a greater understanding of the limitations of the world we live in.

SAMEVATTING†

Daar is al baie gesê en geskryf oor die noodsaaklikheid daarvan om Suid-Afrika se afhanklikheid van goud te verminder. Ten einde te vergoed vir die afname in die land se verdienste van buitelandse valuta as gevolg van die uitfasering van goud wat onvermydelik op die een of ander tyd in die toekoms moet plaasvind, sal daar 'n baie hoër prioriteit aan die ontginning, veredeling en uitvoer van die 59 ander mineraal-kommoditeite wat in Suid-Afrika geproduseer word, verleen moet word.

Die basiese strategie van die mynbou- en metallurgiese bedryf behoort te wees om van die tradisionele benadering om 'n bronbasis daar te stel weg te beweeg na die daarstelling van 'n markbasis; om van produksieoriëntasie na markoriëntasie oor te skakel; en minder op eksplorasie en skaalekonomie, en meer op prosesinnovasie en produkontwikkeling staat te maak.

Die entoesiasme, ondernemingsgees en oorgawe van die leiers in die mynbou- en metallurgiese bedryf sal vanselfsprekend van deurslaggewende belang wees by die vestiging van nuwe nywerhede vir die veredeling en uitvoer van produkte wat op veredelde minerale gebaseer is.

Die Staat kan 'n belangrike bydrae lewer deur die verskaffing van 'n goed ontwikkelde en doeltreffende infrastruktuur, insluitende spoor- en hawefasiliteite, kommunikasie- en gesondheidsdienste, paaie, en die voorsiening van elektrisiteit en water.

In ons soek na 'n nuwe ontwikkelingstrategie vir die veredeling en uitvoer van Suid-Afrika se minerale, moet ons besef dat geen nasie oor al die mineralehulpbronne wat hy nodig het, beskik nie. Kommersiële en strategiese manipulasie van mineraalvoorrade moet nie langer geduld word nie. Die toekoms van die mens lê in internasionale samewerking en in 'n beter begrip van die tekortkominge van die wêreld waarin ons lewe.

Introduction

The essence of the SAIMM, and the secret of its success, is that it is an association of persons who assemble voluntarily as individuals, not to conduct business but to advance the interests of their profession in an environment free of commercial, political, and industrial pressures.

The SAIMM therefore provides an ideal forum for the discussion of local issues that have a profound impact on the future development of the South African mining and metallurgical industry.

The current economic recession has thrown into sharp relief South Africa's critical dependence on foreign-exchange earnings from gold and has stimulated anew the debate on what should be done to reduce this dependence.

In this address an urgent call is made for a national commitment in South Africa to the conversion of our minerals and metals to added-value products prior to export.

* Vice President, Council for Mineral Technology (Mintek), Private Bag X3015, Randburg 2125, South Africa.

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Wealth Outlived?

There are now over five billion people on this Earth. Man has colonized the farthest reaches of the globe, and has proliferated far beyond the numbers that are in stable balance with Nature. The past seventy-five years have seen the human race reach the end of its childhood: centuries of dreams and ambitions have been realized in three remarkable generations.

Our whole way of life, our very survival, depends on the natural resources that we draw from bountiful Earth. The materials that man derives from living matter, such as food and clothing, are renewable resources and are replenished every growing season. But the products of mining are non-renewable one-crop resources, and much of our mineral heritage has already been exhausted. In the first forty years of this century, man consumed more metal than he has mined since the beginning of civilization[1].

Technology has served us well in our craving to push outwards and explore, but now our most important priority is to look inwards again, to concentrate on the Earth sciences, and to reflect on just how long our present way of life can go on before we condemn ourselves, as Shakespeare put it, to 'an age of poverty':

> For herein Fortune shows herself more kind
> Than is her custom: it is still her use
> To let the wretched man outlive his wealth,
> To view with hollow eye and wrinkled brow
> An age of poverty.
>
> *The Merchant of Venice*

Mining, Making, Buying, Using, Discarding

We cannot stop mining, for without minerals civilization would cease to exist: whether the minerals are used as fertilizers to increase crop yields, metals to build machines, materials of construction, or sources of energy, they all have to be won from the ground.

Today, entire industries are devoted to extravagant methods of packaging and presentation in order to promote market growth. Manufacturers manipulate consumer habits of buying, using, and discarding to sustain mass production. Just to maintain our present way of life, each one of us requires over seventeen tons of refined metals and minerals every year.

Several years ago, much attention was being devoted to the depletion of the Earth's non-renewable resources, culminating in the Club of Rome's report[2] of 1972, which conveyed the impression that reserves would be exhausted within one or two life spans. However, the report did not take adequate account of technical advances in the extraction of minerals that would allow lower-grade materials to be treated economically, thus substantially expanding the resource base. In addition, many metals cannot truly be classified as non-renewable, as evidenced by the rising volume of scrap that is being reprocessed and returned to the market. On the demand side, the report assumed exponential growth in the consumption of materials, which does not recognize that increasing industrialization gives rise to greater efficiency of use through miniaturization, substitution, recycling, and longevity.

Nevertheless, it is still an open question as to whether society will eventually have to make a traumatic adjustment: that from growth to non-growth.

The International Minerals Industry

The Industry up to 1950

From antiquity to the Industrial Revolution, there were few applications for metals and minerals other than in warfare and agriculture. Technology was largely primitive, the mining, extraction, and processing techniques being based solely on physical labour. The technical and economic innovations that followed the Industrial Revolution provided the catalyst that led to the creation of an industry characterized by dynamism and rapid growth. Widespread transportation systems gave rise to the exploitation of mineral resources in remote areas, and made possible the economic movement of ores and concentrates to far-distant centres of processing and market demand, thus leading to the growing internationalization of the industry.

Where rich and suitable ores were present, industrialists concentrated on large-scale operations, even though these were still based on traditional and slowly changing technology. Around 1950, when it became clear that domestic high-grade ores were becoming progressively depleted, major mineral producers started the dual thrust of overseas exploration and the development of larger, integrated domestic operations.

As a result of this pattern of growth, the concept of private ownership became entrenched in the industry, and its executives based their activities on the idea of sustainable market growth. Such a strategy was understandable and justified at the time. It seemed pointless to invest in technical innovations or new processing alternatives when rich resources were available overseas. It was better to focus on the economies of scale that could be achieved with proven commercial technologies and so attain the necessary productivity to remain competitive and domestically profitable. Thus, the late 1940s and early 1950s marked the emergence of multinational companies with strong control over international markets. So, the U.S. companies Asarco, Anaconda, and Kennecott established strong positions in Latin America; Anglo American and Consolidated Goldfields linked the continents of Africa, Europe, and Australia; Rio Tinto Zinc developed mines on four continents; and Amax and Inco came to dominate the worldwide production, processing, and sale of molybdenum and nickel respectively[3].

Dynamics of the 1950–1980 Period

Economic reconstruction after World War II provided the initial impetus for three decades of unprecedented growth and geographical diversification in the minerals and metals industries. The restoration of industrial capacity accelerated development in industrialized countries, and gave rise to a remarkable degree of industrialization of the less-developed or Third World countries. All this happened against a background of technical developments in fields that included atomic energy, electronics, space flight, and alternative energy sources.

The period also saw a basic shift of industries from their long-entrenched positions in Europe and North America to developing countries and members of the Eastern Bloc. By 1980, both the developing countries and the Eastern Bloc had more than doubled their proportions of world metal consumption. Combined, they accounted for nearly 40 per cent of the global demand for all major metals[3] (Fig. 1).

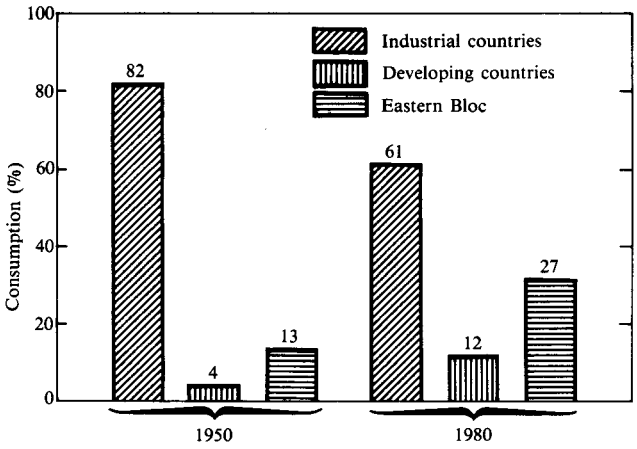

Fig. 1—World consumption patterns for major metals (after Thiers and Wolff[3])

While the metals industry was expanding geographically and becoming more international, the oil-exporting countries formed a price and production cartel in 1960, the Organization of Petroleum Exporting Countries (OPEC). OPEC's first concerted announcement of a major price increase in October 1973 created a worldwide oil crisis, followed by a major economic recession. For the balance of the decade, OPEC's heavy shadow hovered over the world, causing dramatic changes in international balances of payments and credit requirements. The threat of exorbitant energy costs also stimulated the search for alternative sources and energy-conservation measures, which in turn influenced the demand for minerals and metals.

The Devastation of the 1980–1984 Recession

Stemming from the long-term trends that had been established in the previous period, an unusual combination of factors brought about the worst economic recession since the Great Depression. In the industrialized world, optimistic demand expectations had already led to a considerable expansion of production capacity that, even in the absence of other factors, would have caused significant imbalances in supply and demand. Aggravating such a situation, the advent of high energy costs severely depressed consumption through a fundamental change in consumer attitudes. In addition, the rapid rise in oil prices had already set in motion a search for more energy-efficient materials and products, and the more efficient use of metals through improved design and new alloys.

High Technology—Excalibur or the Sword of Damocles?

Future trends in mineral consumption will inevitably follow society's rapidly changing requirements. With every new breakthrough, some materials will become more important, others will no longer be needed, and substances we cannot even find a use for today will suddenly become indispensable, particularly with the advent of high technology. Computers were originally developed to meet the demands of outer space; miniaturization quickly followed; now cybernetics is probably the fastest growing science of all. New machines have revolutionized telecommunications, have changed the face of business, and are capable of conceptualizing design in three dimensions at unnerving speed.

High Tech in Japan

But there is much more to come. One has only to take note of developments in Japan, a country that today ranks second to the United States in terms of gross national product (GNP). Japan's technological capability was the most important factor in enabling it to achieve economic growth rates of 11,6 per cent during the period 1965–1970, 6,2 per cent during 1970–1975, and 5,0 per cent during 1975–1980. The continuing trend in Japan is towards highly efficient, lightweight, miniaturized computer-based products for the information-intensive society of today and tomorrow. Examples of high-technology products already in use or in various stages of development and commercialization are shown in Table I. Raw materials for such products include a wide range of scarce metals for which the current production capacities are inadequate to meet the expected future demand. Examples of end-uses for some of these rare metals are given in Table II.

Intermaterial Substitution

In the past, metallurgists were the masters at creating new engineering materials by dictating the properties of alloys for industrial users. Today, it is more and more the end-user who dictates what properties are needed. Increasingly it is the physical scientist who is turning out new engineering materials, often based on non-metal components such as Noryl®, Kevlar®, and other plastic materials. In the future, the minerals and metal industries will be called upon to increase their understanding of microphenomena, and of market attitudes and trends.

While the rate of technological change is difficult to predict, the implications of specific new developments are important because they illustrate the magnitude of possible future impacts. Given below are three examples[3] of innovations that hold considerable potential for future metal substitution.

- *Electrochemistry*. The deposition of binary alloys containing either nickel and chromium or cobalt and chromium on conventional steel or aluminium substrates. Essentially, the process confers the corrosion resistance and high-temperature performance of stainless steels on bulk aluminium or low-carbon steels, but with a minimal use of nickel and chromium.
- *Metallurgy*. The development of amorphous alloys and new magnetic materials. The former confer high strength and superior corrosion-resistance properties on a variety of metals, but without the losses in ductility expected from crystalline materials. The new magnetic materials far exceed the performance properties of magnets made of cobalt and rare earths, and could therefore lead to the production of very compact electric motors and alternators, and to the use of less copper in coils and windings.
- *Surface chemistry*. The development of new adhesive materials that can obviate welding, riveting, and other joining methods in some of the most exacting applications, such as aerospace. In fact, already produced

TABLE I
HIGH-TECHNOLOGY PRODUCTS UNDER DEVELOPMENT IN JAPAN

Industrial Sector	*High-technology Products*
Machinery	Intelligent robots, super computers, precision machine parts, numerically controlled machines, hydraulic motors.
Electronics	Ultra-large integrations, large-scale memory elements, light-emitting diodes, piezo-electric filters, sensors, oscillators.
New materials	New ceramics, composite materials, engineering plastics, shape memory alloys, microcrystal alloys, superelectric conductors.
Office automation	Super computers, advanced databases, microprocessors, facsimiles, magnetic bubble memories, image processors.
Home automation	Advanced audio equipment, community video, personal computers, new media products.
Chemical industry	Bioreactors, separation membranes, reactive polymers, photopolymerization initiators.
Energy	Amorphous solar cells, photosensitive polymers, separation membranes.
Communications	Artificial satellites, optical fibres, optical lenses, conductive polymers, optical multiplexors.
Medical	Artificial organs, diagnostic reagents, polymer membranes.

TABLE II
RARE METALS IN DEMAND FOR HIGH-TECHNOLOGY PRODUCTS

Gallium	For very large-scale integrations, large-scale memory elements, light-emitting radiation diodes, components for ultra-high speed super-computers, military electronic equipment, and photovoltaic power generation.
Niobium	For special steels, superalloys, amorphous metals, ceramic capacitors, linear motors.
Rare earths	For magnetic heads of micro-tape recorders, catalysts, misch metal and polyphoric alloys, TV glass screens, TV cathode-ray tube phosphors, permanent magnets, X-ray screens, telecom GGG bubble memories.
Ruthenium	For contact points in electronic devices, resistor material in integrated circuits, oxide coatings on titanium anodes.
Titanium	For special steels and superalloys for jet-engine components and airframes in aerospace, space and missile applications, marine industries, defence and new-type armaments, chemical processing, desalination plants, power plants, heat exchangers, electrodes.
Bismuth	For free-machining alloy steels, electronic alloys, low-melting point fusible alloys, industrial catalysts, pharamaceutical applications.
Quartz	For frequency-controlled oscillator plates, frequence filters, resonators, optics, transducer plates.
Silica	For integrated circuits, semiconductors, amorphous silicon solar cells, infrared optics, amorphous metals.

and under test are prototypes of new airplanes that contain panels of composite material glued together with little or no metal content.

Even a small number of such technical innovations, if commercially successful, could dramatically alter the patterns of metal consumption.

Innovations in Mineral Technology

Research and development in mineral science and technology have been neglected in most countries in favour of mineral exploration, development of economies of scale, and the like. The traditional conservatism of the industry, with its emphasis on proven processes, often does not permit process innovations to emerge until the signals of market decline become clear and indisputable.

But what is the potential for real innovations in mineral technology? Here are some possible examples.

- In crushing and grinding, new concepts favouring selective fracturing and liberation along grain boundaries could be considerably more efficient than current practices. Some novel concepts involving electro-acoustic methods have already been tested in laboratories, and show considerable promise in both selectivity and energy efficiency.
- In mineral concentration, cell-less flotation and reagents that are tailored to specific applications in terms of selectivity and recovery may be introduced. Recent studies indicate that bubble–particle interaction and attachment (the basic mechanism of flotation) occur within the impeller zone, implying that simpler configurations of equipment may improve performance. Similar innovations involving systems for the selective separation of ultrafine particles appear equally attractive for future development.
- In hydrometallurgy, the new developments include biological leaching techniques for refractory ores and the development of specific and highly selective organic extractants, such as thiourea-based reagents for the solvent extraction of gold, and phosphine-based reagents for that of common cations.
- In pyrometallurgy, new plasma furnaces will achieve faster reaction rates, as well as improved slag–metal chemistry, and flash-smelting concepts will be adopted extensively for most base metals. In addition, novel concepts of segregation roasting may allow the treatment and economic recovery of base-metal values from hard-to-treat refractory ores.

Reversal of the Traditional Approach

Clearly, if innovations are to succeed, the approach to their implementation cannot be the same as in the past. Because of intense competition, only a few producers will be able to satisfy the need for new metal- and mineral-based products, and their technology must necessarily become highly proprietary. Successful innovations are likely to involve individual entrepreneurship, or the close partnership of metal producers with researchers from academia, State laboratories, and research organizations; such partnerships are likely to be long-lived so that proprietary information can be preserved. The manufacturers of equipment, also facing a depleting market, may enter these partnerships to provide customized equipment and facilities, again on a proprietary basis.

The basic strategy of the mining and metallurgical industries should be to move from the traditional approach of establishing a *resource* base to the establishment of a *market* base; to turn from *production* orientation to *market* orientation; and to rely less on exploration and economies of scale and more on process innovation and product development[4].

The threat of substitution, hanging like the sword of Damocles over the future of the minerals and metals industries, will not be overcome by a slow evolutionary change towards this new strategy. The captains of industry will have to arm themselves for the battle with new products based on minerals and metals—the modern-day equivalents of Excalibur, the legendary sword of the victorious King Arthur.

The South African Minerals Industry

Mineral Production and Exports, 1984

According to the recently published annual review of the Minerals Bureau[5], South Africa produced more than 60 different mineral and metal commodities in 1984. It exported mineral commodities to 87 countries, the largest exports going to North America, Europe, and the Far East.

In 1984, mining and quarrying contributed 13 484 million rands, or 14 per cent, to the GDP, which amounted to 96 678 million rands (Fig. 2). In terms of foreign-exchange earnings, mineral exports accounted for no less than 67 per cent of the total exports. If the various processed mineral products such as the ferro-alloys are included, the contribution by the mineral industry to both the GDP and foreign earnings is significantly higher.

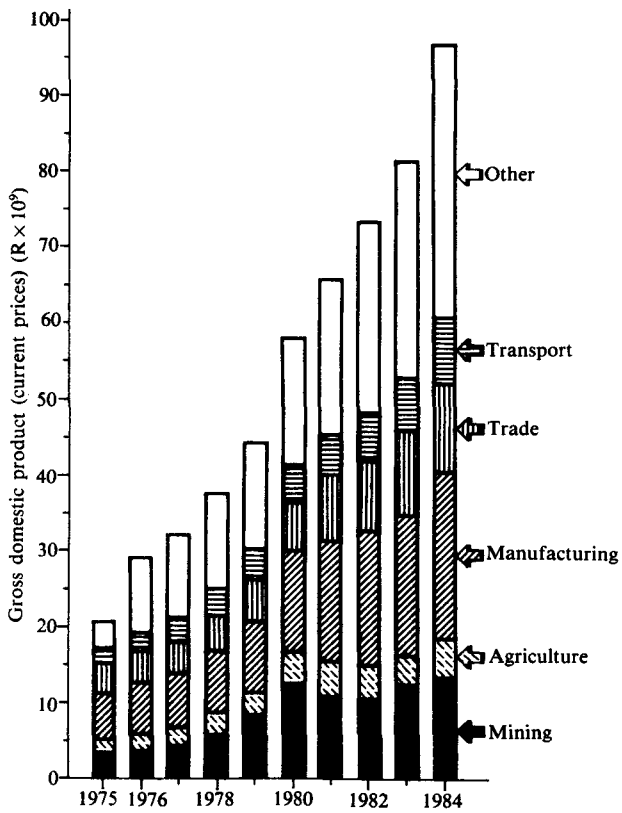

Fig. 2—South African gross domestic product by economic activity from 1975 to 1984 (after Minerals Bureau[5])

The minerals industry is the motivating force behind much of the country's infrastructure and secondary industry. Expenditure on mining supplies and capital projects amounted to no less than 6000 million rands in 1984. Employing 723 000 people earning 4400 million rands, the industry is one of the largest in terms of manpower (Fig. 3).

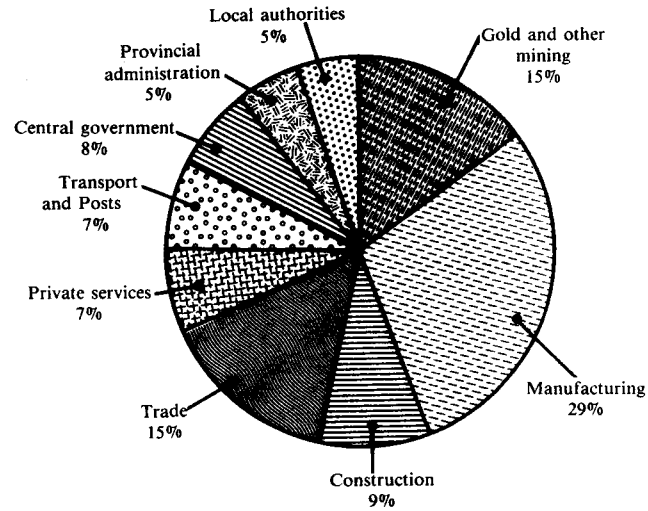

Fig. 3—Employment in non-agricultural sectors in South Africa, 1983 (after Minerals Bureau[5])

The industry achieved a very satisfactory performance in 1984. The total value of mineral sales increased by 17 per cent, from 16 244 million rands in 1983 to 19 008 million rands. Export revenue at 16 041 million rands accounted for 84,4 per cent of total mineral sales, representing an increase of 16,8 per cent on the 1983 figure of 13 733 million rands. Most of the commodities exported showed substantial real growth both in earnings and in price.

Gold sales accounted for 60,8 per cent of the total mineral earnings, and 72,1 per cent of export revenue (Fig. 4). Both these figures are the lowest for several years and indicate the increasing contribution of the non-gold sector. Exports from the latter increased in revenue by 26,1 per cent to 4482 million rands, accounting for 27,9 per cent of the total mineral exports.

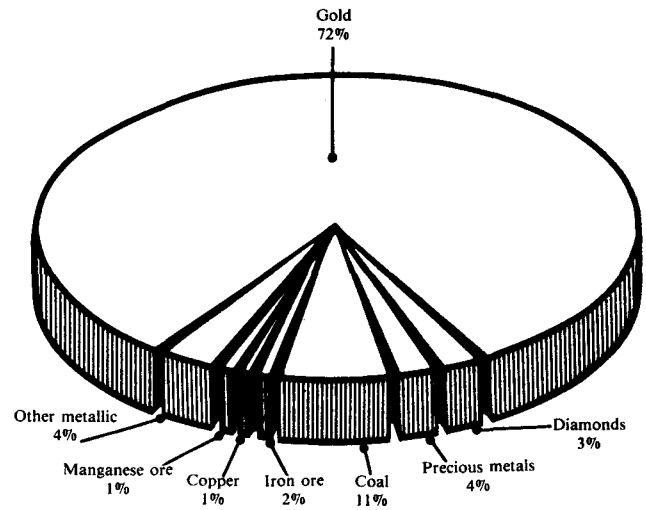

Fig. 4—Mineral export sales from South Africa, 1984 (after Minerals Bureau[5])

South Africa's Dependence on Gold

South Africa's gold mines have produced about one-third of all the gold mined by man since the beginning of history, with a cumulative output of about 39 544 tons since mining commenced during the early 1870s to the end of 1984. Although the annual production peaked in 1970 at 1000 tons and has since dropped by one-third (Fig. 5), South Africa's dependence on gold has steadily increased during the past twenty-five years. This is evident from the fact that gold, as a percentage of South Africa's total export revenue, increased from less than 30 per cent in 1950 to about 50 per cent in 1984, the increase in the price of gold taking up the slack caused by the drop in production.

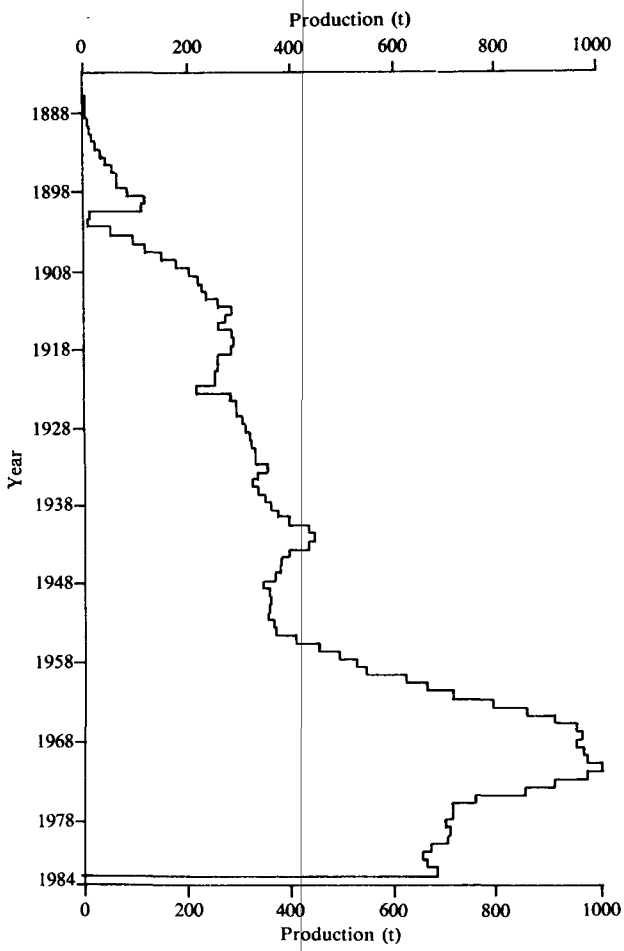

Fig. 5—South Africa's gold production from 1884 to 1984 (after Minerals Bureau[5])

For a number of years, conventional wisdom has held that South African gold production would halve by the end of the century. More recently, the Chamber of Mines of South Africa pointed out that, because payable ore reserves have always been estimated on a five-year rolling basis, the production curve has consistently appeared about to peak towards the end of each period, no allowance having been made for expansions and new mine developments. A more realistic assumption is now considered to be one in which the production will tend to rise back towards 700 tons per annum in the short term, remaining close to that level until the end of the century[6].

It is estimated that another 20 000 tons of gold could be produced by South Africa over the next 40 to 50 years (15 000 tons from known mines, and the remaining 5000 tons from new mines). Although the proving of additional ore reserves, the commissioning of new gold mines, and improvements to the recovery processes may postpone the final phasing-out of gold, it is generally agreed that the number of mines will decrease to the point where gold production will eventually terminate[7] (Fig. 6).

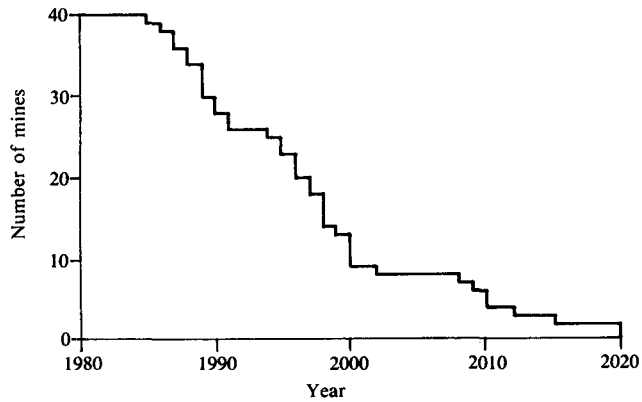

Fig. 6—Number of producing and developing gold mines from 1980 to 2020 (after Camisani-Calzolari[7])

Much has been said and written about the need to reduce South Africa's dependence on gold. It is generally agreed that, to compensate for the decline in the country's foreign-exchange earnings resulting from the phasing out of gold, a far higher priority will have to be placed on the mining, beneficiation, and export of the 59 other mineral commodities that South Africa produces. At the same time, greater emphasis will have to be placed on the export of manufactured goods.

Growth of Beneficiation in South Africa

The terms *beneficiation, further processing, upgrading, refining,* and *enrichment* tend to be used interchangeably to describe more or less the same thing, the particular term used being mostly a matter of preference. In the discussion that follows the term *beneficiation* is used throughout.

Beneficiation refers to the process or series of processes by which an ore containing a metal or mineral as it is found in Nature is converted into a product containing a progressively higher concentration of the metal or mineral concerned. The final result is achieved when the metal or mineral reaches the highly beneficiated or chemically pure form required by the end-user. *Beneficiation* ends and *manufacturing* begins when the mineral commodity has been converted into a final usable product. Gold, for instance, reaches the peak of beneficiation when a bar of 99,995 per cent purity is cast; jewellery made out of such a bar is a manufactured product.

It is evident that the trading of a processed mineral product essentially involves the selling of raw material plus labour plus technology plus energy.

The Period up to 1972

Examples of beneficiation operations launched in South Africa during the period up to 1972 are AECI, Vereeniging Refractories, Usco, Dunswart, Iscor (1928), Scaw Metals, Huletts Aluminium, Amcor (1942), Matte-Smelters-JCI, Sasol 1 (1955), Chromium Chemicals-Bayer, Southern Cross-MSA, Highveld Steel and Vanadium, Zincorp, Delta Manganese, and Alusaf (1972).

Reynders Commission 1972

The Commission of Inquiry into the Export Trade of the Republic of South Africa[8] (the Reynders Commission) reported in 1972 that ores, minerals, and metals offer the best opportunities for increased exports in the short and medium term, and that the main bottle-necks are shortcomings in the infrastructure, insufficient metallurgical research, lack of an aggressive marketing policy, and the unfavourable conditions prevailing at the time on the credit market.

The Commission made the following important recommendations in regard to mineral exports:

- the responsible bodies should pay serious attention to the improvement and expansion of the infrastructure (including bulk handling systems) for fast exportation of ores and minerals;
- the potential for the beneficiation of ore and minerals within the Republic should be exploited as far as possible within the limits of economic feasibility;
- the research efforts (including research into beneficiation processes) by State bodies, as well as private concerns, should be increased and coordinated.

The Period 1973 to 1980

These recommendations were followed up by both the State and the private sector, with the result that a large number of new operations were initiated during the period 1973 to 1980. Examples are Lonrho Refinery, Feralloys-Machadodorp, Transvaal Alloys, Matthey Rustenburg Refineries-JCI, Antimony Products, Tubatsi, CMI-JCI, Impala Platinum Refinery, Sasol 2 (1975), Silicon Smelters, Richards Bay Iron and Titanium (1977), and Sasol 3 (1979).

Lack of New Ventures since 1980

Since 1979 only one new beneficiation plant (Western Platinum Base Metal Refinery) has been launched in South Africa. This appears to signify an abrupt halt in recent years in the growth of the beneficiation industry, which gives cause for considerable concern and, in the national context, could have very serious implications for South Africa.

Economic Factors Significant to Growth in South Africa

The world economy has reached absurd extremes: manipulation of paper and cashing in on interest rates are now generally regarded as more profitable than investment in exploration, mining, mineral processing, or industrial manufacturing. Speculation proliferates. Huge artificial markets are created, and influences outside the stock exchange control and distort the value of mineral commodities.

Because of the structural changes that have taken place in the world economy during recent years, South Africa is being confronted by new challenges in development policy and strategy.

With the publication, in May 1985, of a White Paper on Industrial Development Strategy in the Republic of South Africa[9], the State recognized the need to reconsider the direction of industrialization, and to adopt measures that will foster the development of the country's manufacturing industry.

Without detracting at all from the importance of developing South Africa's manufacturing industry, it is clear that the country's first priority should be to concentrate on its greatest strength, which undoubtedly lies in its tremendous mineral potential. It goes without saying that the State must give urgent attention to the adoption of measures that will foster the development of South Africa's mineral industry.

Both with regard to mineral beneficiation and manufacturing, there are a number of economic realities that need to be considered in the search for new development strategies.

Concentration of Economic Power

Widespread concern has been expressed about the extent to which a limited number of financially powerful business groups dominate South African industry and commerce.

It is important that we retain a balanced view in this matter. Without the contribution of the big groups, our economy would not have reached its present level of development and sophistication. We would not have been able to compete successfully in foreign markets in many fields of economic activity, and we would have been more dependent on imported equipment and products.

The potential disadvantages of the concentration of economic power were outlined[10] in 1983 by the Minister of Industries and Commerce, who made the following points.

(i) A dominant business group in the market might use its size and power to increase its domination rather than its efficiency.
(ii) Competition is essential to motivate management in seeking more effective ways of manufacturing products or providing services, and in looking for cost-reducing processes.
(iii) Powerful groups might be inclined to complacency, and might fail to make the necessary contribution to the economy in the form of new development.
(iv) The numerous take-overs during the past ten years have created the impression that the emphasis has shifted towards growth by acquisition, rather than by real development.
(v) Investment should be directed into fields where there is a shortage of production capacity, as well as towards import replacement, new export markets, and the beneficiation of raw materials.

Productivity

There is no doubt that, seen in the African context, South Africa is an industrial giant. Yet, sadly, this giant has demonstrated a complacency about industrial out-

put that it can ill afford. The improvement of productivity has until recently not been regarded as a priority because the country is richly endowed with natural resources and a large labour force—all of which were taken for granted. Thanks to extended coal resources, energy has never been a bottle-neck, and capital (although scarce) has always been available[11].

M.T. de Waal, of the Industrial Development Corporation (IDC), has said[12] that, over the past decade, South Africa's capital investment as a percentage of its GDP was considerably higher than in even the advanced industrialized countries, with the exception of Japan (e.g. 17,8 per cent in Britain, 23 per cent in Australia, 16,4 per cent in India, 31,8 per cent in Japan, and 27,2 per cent in South Africa). However, in spite of the high investment level, the country's growth in real GDP since 1973 was only 2,8 per cent, much less than the performance of other semi-industrialized countries (e.g. 7,6 per cent in South Korea and 4,1 per cent in Australia). Furthermore, South Africa seems not to have derived any of the benefit in worker productivity that high investment levels are supposed to bring (comparable figures for 1973–83 are South Korea 4,6 per cent, Australia 3,0 per cent, and South Africa 1,4 per cent). Also, notwithstanding the high input of capital since 1973, new employment opportunities in South Africa grew at only 1,4 per cent a year, far short of the 2,5 per cent needed.

However, these statistics should be viewed in the light of the fact that the relatively high capital investment in the past arose from the need for national self-sufficiency in energy, fuel, arms, and other strategic industries; as these are unlikely to require the same priority in future, the economy could now become much more market orientated.

What these figures nevertheless show is that the disappointing growth in GDP, the low level of new employment, and the inadequate productivity per worker, coupled with a decline in personal savings to finance new ventures, now compel South Africa to critically analyse its future pattern of investment, and thus the level of technology it can afford.

First World—Third World

South Africa is also faced with a special dualism in the composition of its population: namely, a strongly developed First World element living cheek by jowl with a relatively large underdeveloped Third World element. Within this environment, the economic factors that determine and direct the welfare of this country must be deployed to the greatest benefit of all the inhabitants of the country. In addition, it must be remembered that the natural local market is relatively small and that South Africa is isolated in numerous respects.

In consequence of this, the State has to ensure that a sufficiently strong and sound infrastructure is established—an infrastructure on which private initiative will best be able to build and develop within a capitalistic system. It must also be able to resist, restrict, and even prohibit unnecessary wastage of scarce resources and to apply the necessary controls. This implies that the State will act as entrepreneur in essential areas in its performance of this role. But this action should never be seen as malicious interference by the State in the activities of the private sector[13].

Call for Added Value

Against the background outlined above, Dr A.M. Edwards, President of the Council for Mineral Technology (Mintek), recently made an urgent call for a re-assessment of South Africa's development strategy in the beneficiation and exportation of its minerals and metals. Some of the points he highlighted[14] are as follows.

(a) South Africa could double its foreign-exchange earnings within ten years by adding value to its mineral exports.
(b) South Africa is already a proven leader in ferrochromium products for the production of stainless steel, and yet it produces less than 1 per cent of the world's stainless steel. If only half of the ferrochromium produced were converted to stainless steel in South Africa, the country could earn in the region of 4000 to 6000 million rands a year.
(c) South African chromium is the preferred raw material for the manufacture of chromium chemicals, and yet only 2 per cent of the world's production of these chemicals takes place in South Africa. The potential is there for the expansion of this industry to earn another 200 million rands a year.
(d) South Africa supplies a quarter of the world's requirements of titanium oxide, but less than 1 per cent of the world's titanium pigments. The production of these pigments in South Africa could earn the country another 300 million rands a year.
(e) In every category of mineral—platinum, manganese, vanadium, diamonds, fluorspar, and gold—there is the possibility for further added value.
(f) The fact that it takes ten years for a major industry to come into being means that the situation is now urgent.

Constraints to Further Processing

The benefits that could accrue from the further processing of South Africa's minerals prior to export are very considerable, but there are many constraints that need to be recognized[15].

(1) A production plant for further processing may be more capital-intensive than the mining or intermediate processing steps.
(2) Further processing often inherently implies a greater dependence on high technology.
(3) The combination of capital-intensive plant with relatively advanced technology requires a greater proportion of educated, trained, and skilled manpower, and this is already in short supply.
(4) Because of its historical development, the South African mining and metallurgical industry tends to invest more readily in a new mining activity associated with partial processing than in one concerned with further processing.
(5) In the case of many mineral and metal commodities, the international reputation that has been gained by South Africa for its expertise in mining and partial processing does not yet extend as widely to processing steps that lead to end-products.
(6) Further processing usually means that marketing requirements increase, and specifications become more

complex for mineral and metal products.

(7) The highly industrialized nations derive a significant proportion of their GDP from the manufacturing sector, which is often based on imported raw materials or on intermediate-processed mineral and metal commodities. The customs and import duties levied by these countries to protect domestic beneficiation industries militate against South Africa's penetration of established international markets for beneficiated products.

(8) The most commonly mentioned advantages of the South African mining and metallurgical industry, i.e. access to large reserves of raw materials, relatively cheap energy, and comparatively low-cost labour, are continuously at risk. The large reserves are often of low grade, and are increasingly difficult to mine and process economically; the price of electrical energy is beginning to approach that of some competitors; and the labour costs are increasing rapidly, with a decrease in the wage gap between the various levels of skills, and with inflation and relatively low productivity.

(9) The existence of a local market for a mineral or metal product can be very important when it comes to the establishment of a new venture. The local market provides a base-load for the new product, and, when a producer has gained confidence from his local sales, he can increase his production with the object of entering the export market. The disappointingly slow growth in the local manufacture of consumer goods for export severely limits the South African market for intermediate-processed added-value mineral products, and places a severe constraint on the establishment of new beneficiation industries.

Where There's a Will There's a Way

The history of South Africa bears testimony to the fact that problems can be solved and used to advantage, provided they are tackled with the necessary zeal, expertise, and determination. This is the attitude that made South Africa the strong and go-ahead country it is today. But if we want to continue on this road, we must ensure that we identify our problems timeously and honestly, and do something about them.

Perhaps we should draw our inspiration from men like Dr Hendrik van der Bijl, who pioneered the establishment of the Electricity Supply Commission (Escom), the Iron and Steel Corporation (Iscor), and the African Metals Corporation (Amcor)[16].

As early as 1920, Dr Van der Bijl said that he liked to think of the industrial growth of South Africa as an enormous shady tree giving shelter and sustenance to the people of the land. The roots he thought of as gold, coal, iron ore, copper, manganese, lime, and the almost unlimited mineral wealth so generously provided for us in the soil of our land. Man had only to use his ingenuity in cultivating these roots and up would spring a most wondrous tree. One of the main tap roots—gold—had already been developed into so vast an industry that South Africa was beginning to take the form of an upturned pyramid, balanced precariously on the point of gold—a dangerous and alarming state of affairs.

Dr Van der Bijl was shocked at the complacency with which South Africans in general were accepting this unstable state of affairs for, as he himself put it, 'South Africa's life is hanging by a thread of gold', and he determined with all the fervour of youth to do his utmost to develop some of the other roots and make a more stable structure. He did not underestimate the power of gold, and appreciated the efficiency of the gold-mining industry—it was a deep and powerful tap root and looked like holding up the tree for quite a while.

The trunk of his industrial tree was, of course, steel—good strong steel (preferably Iscor's), and the life-giving sap would be his cheap and abundant supply of electric power (provided by Escom). The branches, he felt, would take care of themselves, especially if they were given plenty of encouragement.

Wise words indeed, and as relevant today as they were sixty-five years ago.

The constraints to beneficiation mentioned above, and the threat of substitution, hanging like the sword of Damocles over the future of South Africa's mineral industry, should not be taken lightly.

What South Africa clearly needs *now* is a national commitment and an overall strategy to unlock the obvious latent potential that exists for the beneficiation (further processing) of its minerals and metals prior to export. The challenge is formidable—the rewards will be enormous.

Here, again, it is instructive to reflect on the philosophy propounded by Dr Van der Bijl and used so successfully in all the industries that he launched. He said 'the mere conception of an idea is only a germ cell, and it requires an army of experts to give it careful nursing, persevering thought and an almost unlimited painstaking effort to bring it to a state of maturity'.

Minerva—Goddess of Wisdom

As regards beneficiation, South Africa is in the fortunate position of having

- substantial resources of a wide range of mineral and metal commodities;
- sufficient coal reserves to generate electric power at competitive prices;
- a sound research and development infrastructure in mineral science and technology;
- a financially strong and dynamic mining and metallurgical industry; and
- a stable Government that consistently directs its mineral policy towards ensuring that mineral development is based on private enterprise within a legislative and fiscal environment that both attracts investment and allows for equitable returns on such investment.

The Council for Mineral Technology (Mintek) recently launched an investigation into South Africa's potential for added-value mineral and metal exports. In the tradition of research organizations, a codeword had to be coined for the project and the choice fell upon MINERVA (*Miner*als *V*alue *A*dded). According to Roman mythology, 'though wisdom is of slow growth, Minerva, daughter of Jupiter, sprang from his brain full grown and clad in a coat of mail'. In art, Minerva is represented in full drapery with helmet, shield, and spear, but she had no desire for conquest and was known as the goddess of wisdom.

At this stage, Project Minerva involves the preparation of a series of commodity charts each comprising a 'family tree' that uses blocks and lines to illustrate the association of the products, in increasing order of sophistication, that can be prepared from a raw material. The degree of South Africa's current activity in processing is illustrated by a colour code: red indicates major involvement, yellow signifies a minor but growing activity, and blue identifies products that could potentially be made in South Africa in the future. Examples of such family trees are shown in Fig. 7 (chromium), Fig. 8 (titanium), and Fig. 9 (gold).

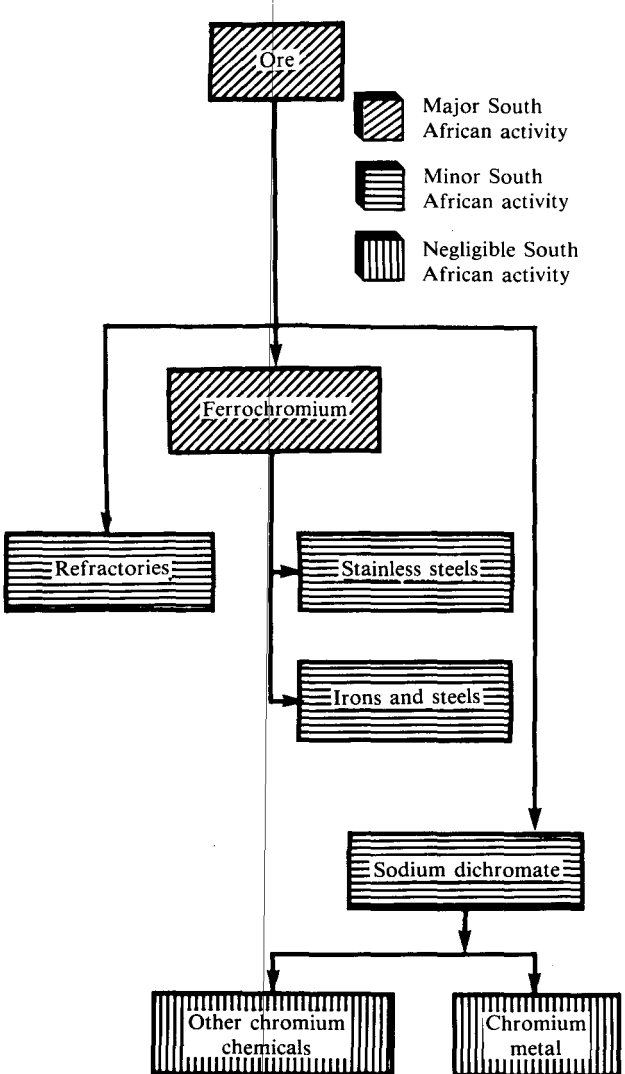

Fig. 7—Chromium family tree

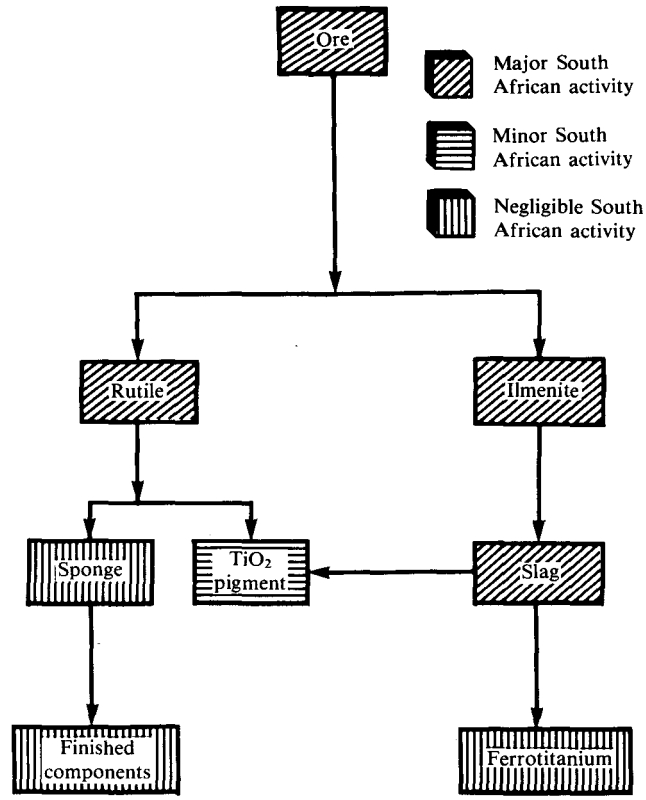

Fig. 8—Titanium family tree

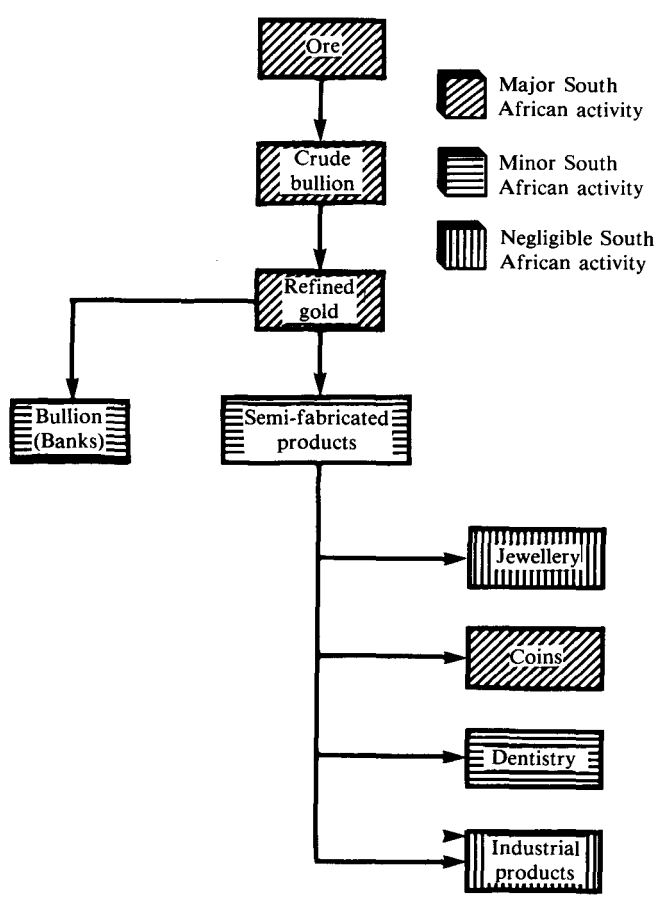

Fig. 9—Gold family tree

The main objective of the charts is to pin-point areas that should be emphasized in research and product development with the ultimate aim of establishing new industries in South Africa for the beneficiation and export of mineral-based added-value products.

What makes Project Minerva different from previous initiatives in this direction is that the question of further processing is being looked at through the technology-tinted glasses of engineers and scientists. This really means that the emphasis is on the use of the sound R&D

infrastructure in mineral science and technology that already exists in South Africa as a springboard to creating new thrusts in the area of mineral beneficiation.

South Africa's impressive track record in mineral technology research is illustrated by the following[17,18].

(a) It is accepted internationally that South Africa is a source of expertise and innovation in several fields of mineral science and technology. Notable examples are the refining of the platinum-group metals, the application of activated carbon in the extraction of gold, the computer control of ferro-alloy furnaces and grinding mills, the extraction of uranium, the design of flowsheets for the recovery of andalusite, and the application of plasma technology to the smelting of chromite for the production of ferrochromium[19].
(b) Special skills include the ability to synthesize resins, solvents, and reagents for new mineral-processing applications, the expertise to develop instruments that are not available commercially, and the application of sophisticated analytical and mineralogical techniques to the solution of fundamental and practical problems in mineral processing.
(c) South Africa's prominence in the fundamental study of various aspects of mineral and process chemistry, and in the application of scientific principles to mineral-processing practice, is well established.
(d) The importance of facilities for pilot-plant testing at Mintek and in industry is well recognized, and they continue to be extended, particularly in areas such as bacterial leaching, novel furnace design and operation, and advanced chemical-processing techniques relevant to the further processing of a number of mineral commodities.

It is evident that subsequent phases of Project Minerva will involve in-depth studies of specific potential growth areas for further processing that emerge from the first phase of the investigation. An essential step in all these projects will be the techno-economic evaluation of existing or new processes. In certain cases it is very likely that considerable research will have to be undertaken to adapt existing processes to South African conditions or to develop novel alternative process routes. It is clear that such investigations will involve very close cooperation and interaction between Project Minerva, the private and public sectors in South Africa, and the international minerals and metals industries. These interfaces are illustrated in Fig. 10.

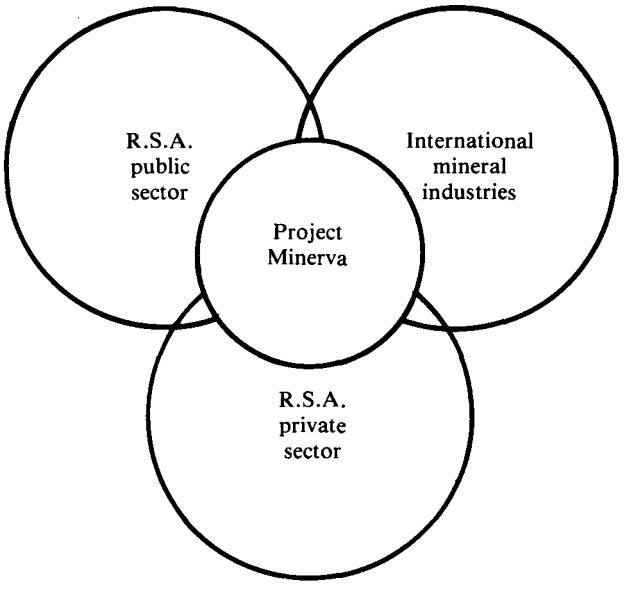

Fig. 10—The interface between Project Minerva, the private and public sectors in South Africa, and the international mineral industries

Collaboration between the Private and Public Sectors

In the section that follows a brief resumé is given of the many different organizations in the private and public sectors in South Africa that have a contribution to make towards the development of the minerals sector.

The Mining and Metallurgical Industry

The South African mining industry differs from those of other countries in that most of the large operations, which together account for 85 per cent of the value of mineral sales, fall within the orbits of six major mining houses.

These groups cooperate in matters of common interest through the Chamber of Mines of South Africa, whose major technical activities encompass the processing and marketing of uranium concentrates through the Nuclear Fuels Corporation (Nufcor), the refining of gold and silver at the Rand Refinery, and the marketing of Krugerrands through the International Gold Corporation (Intergold). In addition, the Chamber carries out research in mining, and Chamber members lead the world in the intricacies of deep-level gold mining and all that it entails.

The Transvaal Coal Owners' Association (TCOA) markets coal on behalf of its members, carries out market research, promotes the sale and usage of coal, and conducts viability studies to improve the distribution of coal. It comprises an association of 25 collieries (of which two are geared exclusively for the export market), and forms an important link in the communications chain between producers and consumers.

Other organizations have been formed to assist specific sectors of the industry. These include the Aluminium Producers' Association, the Copper Development Association, the Ferro Alloy Producers' Association, and the Chromium Centre[20]. The Steel and Engineering Industries Federation of South Africa (SEIFSA) is a large umbrella organization under which the associations of numerous industries working in the fields of mineral processing, recycling, and utilization operate.

Satellite Industries

The satellite industries supply the range of raw materials, consumables, spares, and services that are essential for mining and processing operations. They include the manufacturers of equipment, producers of special chemicals (such as explosives, flotation reagents, resins, solvents), and engineering and construction firms.

Financial Organizations

Because mining houses are not always able to finance

new projects from retained earnings, private and international banks, institutional finance organizations (such as insurance companies, and retirement and pension funds), and private investors also play an important role.

The State

The role of the State in the mineral industry manifests itself in various ways[5].

One of the State's main objectives is to maintain an economic and fiscal structure within which the private sector can conduct exploration for new mineral deposits and profitably mine, beneficiate, and market the country's mineral resources.

The State has the responsibility to provide a well-developed and efficient infrastructure, including rail and harbour facilities, communications and health services, roads, and the supply of electricity and water. By way of illustration, in 1984 South Africa exported some 60 Mt of bulk mineral products (excluding the large volume of minerals shipped via South Africa by neighbouring and central African countries).

The Department of Mineral and Energy Affairs

The administration of South Africa's mineral laws is the responsibility of the Department of Mineral and Energy Affairs, supervision being under the control of the Government Mining Engineer.

The Geological Survey undertakes geological mapping and basic studies relevant to the occurrence, genesis, and identification of ore deposits, and disseminates this information through reports and other publications. The Minerals Bureau collects, classifies, and analyses mineral data that can assist the Government in formulating policies on mineral development, and provides assistance to the industry by way of minerals intelligence.

The Statutory Research Councils

The Council for Mineral Technology (Mintek) is one of the largest organizations of its kind in the world. Its primary aim is to promote mineral technology by undertaking research into the properties, composition, recovery, extraction, processing, refining, and utilization of minerals and metals.

The National Institute for Materials Research (NIMR) of the Council for Scientific and Industrial Research (C S I R) carries out fundamental research aimed at an improved understanding of the mechanical, physical, and chemical properties of metals and alloys, as well as of fabricated components, in terms of their microstructure and its dependence on alloy composition and processing parameters.

The Industrial Development Corporation

The share capital of the Industrial Development Corporation (IDC) is held entirely by the South African State, but it conforms to private-sector company practice in its operations and administration.

The objectives of the IDC are as follows:

- to provide medium to long-term finance to the private sector for the development of viable secondary industry in South Africa;
- to underwrite the development of new industries on a selective basis in South Africa;
- to encourage the development of industries that, in particular,
  - are relatively labour intensive,
  - have substantial export potential, and
  - will introduce desirable new technology into the South African economy;
- to promote regional development and the upgrading and better utilization of South Africa's labour resources;
- to assist in the formulation and implementation of appropriate industrial strategies.

National Commitment

There is room for greater collaboration between the private and the public sectors on the question of further beneficiation of South Africa's minerals. Indeed, there is an urgent need for a national commitment to the conversion of our minerals and metals to added-value products prior to export.

Conclusion

How much better it is to get wisdom than gold!

Proverbs: Chapter 16, Verse 16

Much has been said and written about the need to reduce South Africa's dependence on gold. It is evident, however, that, to compensate for the decline in the country's foreign-exchange earnings resulting from the phasing out of gold, a far higher priority will have to be placed on the mining, beneficiation, and export of the 59 other mineral and metal commodities produced in South Africa. At the same time, greater emphasis will have to be placed on the export of manufactured goods.

Future trends in mineral consumption will inevitably follow society's rapidly changing requirements. With the advent of high technology, some materials will become more important, others will no longer be needed, and substances we cannot even find a use for today will suddently become indispensable.

In the past, metallurgists were the masters at creating new engineering materials by dictating the properties of alloys for industrial users. Today, the end-user dictates what properties are needed.

The basic strategy of the mining and metallurgical industries should be to move from the traditional approach of establishing a *resource* base to the establishment of a *market* base; to turn from *production* orientation to *market* orientation; and to rely less on exploration and economies of scale and more on process innovation and product development.

The benefits that could accrue from the further processing of South Africa's minerals prior to export are very considerable, but there are many problems that need to be overcome. The history of South Africa bears testimony to the fact that problems can be solved and used to advantage, provided that they are tackled with the necessary zeal, expertise, and determination.

Mintek recently launched project Minerva—an investigation into South Africa's potential for added-value mineral and metal exports. The emphasis is on the use of the sound R&D infrastructure in mineral science and

technology that already exists in South Africa as a springboard to creating new thrusts in the area of mineral beneficiation.

It is instructive to reflect on the philosophy propounded by Dr Hendrik van der Bijl and used so successfully in the many new industries that he launched: the mere conception of an idea is not enough; it requires an army of experts, persevering thought, and an almost unlimited painstaking effort to bring it to a state of maturity.

The enthusiasm, entrepreneurial spirit, and commitment of the leaders in the mining and metallurgical industry will clearly be of decisive importance when it comes to the establishment of new industries for the beneficiation and export of added-value mineral-based products. Equally important is the enormous potential of the six major mining houses for mustering the high-level manpower and financial resources required to get such ventures off the ground.

The State can make a significant contribution by the provision of a well-developed and efficient infrastructure, including rail and harbour facilities, communications and health services, roads, and electricity and water supplies.

In the minerals industry, the enormous initial capital cost of a beneficiation project and the long lead time before the payment of dividends to shareholders are inhibiting factors. The benefits to be derived are determined by the competitiveness of the local producer compared with that of producers in countries having similar minerals or processing facilities. Thus, although South Africa may have a significant share of the raw-product market, a significant share of the beneficiated market is not assured.

Competitiveness in the medium and long term on international markets is accordingly of crucial importance to new ventures. Where the comparative advantage is not patently clear, the matter of State incentives and allowances and their continuing certainty are of fundamental importance to any investment in the beneficiating process.

One important reason for the dearth in South Africa of new ventures in further processing is that added-value commodities are produced in the industrialized countries by companies that, apart from possessing a high level of technical expertise, jealously guard their market outlets. Indeed, virtually every new metallurgical development in the past decade in South Africa has involved the participation of an international partner who possesses technical or marketing information, or both.

Although mining and extractive metallurgy are as important as ever, physical metallurgy in all its facets is assuming more and more importance as the mineral-beneficiation industry expands and the accent shifts to product development and the export of manufactured goods. It is evident that the very close technical interaction that is necessary between the mining, extractive metallurgy, and physical metallurgy sectors in South Africa can best be promoted within a single umbrella organization like the SAIMM.

What South Africa urgently needs is a national commitment on the part of both the public and private sectors to work together towards unlocking the obvious latent potential that exists for the conversion of the country's minerals and metals to added-value products before export.

In our search for a new development strategy for the beneficiation and export of South Africa's minerals, we need to recognize that the world is a single, isolated organism and no one nation has all the mineral resources that it needs—we are all utterly interdependent. Commercial and strategic manipulation of mineral supplies should no longer be tolerated. The future of the human species lies in international cooperation and in a greater understanding of the limitations of the world we live in.

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