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DATA SUMMARIES OF KEY COMMODITIES IN THE
SOUTH AFRICAN MINERALS ECONOMY

C. F. VERMAAK

• INFORMATION CIRCULAR No. 118

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by

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INTRODUCTION

The following review summarizes data on twenty-one metal and mineral commodities which are important to the South African and world economies. Eventually the most pertinent data has been abstracted and compared. An appendix furnishes definitions, and explains and augments certain standards, terminologies and abbreviated designations utilized in the data summaries. The appendix also provides some guidelines as to the confidence that can be placed in the data utilized.

Because of its noteworthy mineral production and its large reserves and resources of strategically vital mineral commodities, the mineral industry of the Republic of South Africa is a significant factor in the mineral economy of the world. Its mineral industry has been of major consequence in this country's development and continues to be the principal sustenance upon which the economic growth of the country is based. In 1974, mining contributed some 12% of the gross domestic product and minerals comprised 57% of this country's total exports. In 1975, the official value of mineral sales amounted to R4 134 195 184, an increase of 5,24% on the previous year; the quoted figures do not indicate the confidential sales value of the platinum-group metals and uranium. Estimates of total 1975 mineral sales, including those officially exempted minerals, amount to R4 463 185 784, of which base and industrial minerals contributed about one-third of the value (33,2%) and precious metals and diamonds the balance. By far the most important mineral commodity produced is gold which constitutes 61,93% of official sales and 57,36% of estimated sales.

Free enterprise and private ownership of mines is officially encouraged in South Africa and consequently the mining industry is one of the most progressive and viable in the world. The State does, however, participate in the industry either through lease agreements and royalties or through the Industrial Development Corporation of South Africa and has thus entered into large-scale exploitation and processing of ferrous metals, coal and phosphate rock. The Department of Mines administers the legislation governing mineral exploration, development and exploitation with special regulations applicable to radioactive and prescribed minerals, precious stones and natural oil and gas. The State also operates, and is in the process of expanding, synthetic oil-from-coal plants and has refinery interests, although the large bulk and crude petroleum refinery capacity is operated by the international oil companies. Public authorities own and operate all utilities, the expanding rail-transportation and harbour facilities, as well as the country-wide electrical generating capacity. Mineral commodities are transported mainly by rail to domestic consumers or for export to the major ore-handling ports, Port Elizabeth and Durban, although some portion of the mineral production is exported through Maputo in Mozambique. New ports, constructed principally for the export of iron, manganese, chrome and coal, include the east-coast port of Richards Bay and the west-coast port of Saldanha Bay; the projection being that these ports will treble the country's total mineral export volume and especially of the commodities under review.

The universal realisation of the finite nature of currently economically exploitable mineral reserves and resources has been emphasized by the 1973 energy crisis, as has been the powerful resources weapon which the mineral-endowed countries wield. The consequence has been a re-evaluation of the existing reserve and resources inventories especially in countries such as South Africa whose economies are highly dependant on the performance of their mineral industries. Without this inventory appraisal, the forward optimal planning of all aspects of the mineral economy, including geological, metallurgical and mining research programmes, would not be possible.

The recent revival of the Malthusian theory by many organisations such as the Club of Rome, reflects the popular awareness and concern regarding the importance of the natural resources which support the continued well-being of the world's population. According to some opinion, the basic economic problem is not merely the world population growth (1,9% from 1960-1975; exceeding 4 thousand million persons in 1975), but the rapidly increasing proportion (12,5% in 1970, increasing 4,7% per annum) of the world's affluent middle class which utilizes up to 5 times the raw materials compared with the poorer population and destroy the environment in the process. The real issue is thus not how many people can live on our globe but how many can live well! Opinion is strongly divided regarding the future of the world's mineral resources. Some authorities paint a gloomy picture of non-renewable and finite resources while others reason that mineral reserves are dynamic and consequently place a high reliance on technology to find the means of converting resources of ever-decreasing grade into exploitable reserves.

A real challenge to the South African Mining industry is to find sources of the mineral commodities which she imports as follows (based on 1972 tonnage) : potassic and nitrogenous fertilizers, 34,9%; elemental sulphur, 23,5%; clays, 17,3%; aluminium, 13,2%; magnesite, 10,3%; soda and potash compounds, 0,8%; and lesser amounts of mercury and tungsten. An equally compelling challenge is to manufacture products internally from the mineral commodities which she produces. South Africa remains a net importer of manufactured goods made of precious metals (Total 18 070 kilograms: silver, 98,1%; gold, 1,2%; platinum-group metals, 0,7%), diamonds (Total 103 294 carats) and base-metal and industrial products (Total 1 191 235 tonnes: iron and steel, 66,3%; chromium, 10,4%;

stone, 6,2%; cement, 5,1%; copper, 3,7%; zinc, 2,5%; slag, 2,4%; lead, 1,9%; asbestos, 1,4%; with lesser amounts of tin, titanium, tungsten, cobalt, manganese, magnesium, silicon, tellurium, molybdenum, boron, phosphorous, barite, graphite, gypsum, mica, pigments, salt and talc). She naturally imports all her crude petroleum (see below).

The minerals dealt with in this review make up 88,9% of total official South African mineral sales and 89,7% of estimated total mineral sales. The sales value of the minerals dealt with is proportioned as follows: precious metals, 74,22%; diamonds, 0,25%; and base and industrial minerals, 25,53%; commonly some 48,20% of the latter materials are exported. The metal and mineral commodities reviewed are as follows, with their contributing sales value and proportion of exports respectively shown in brackets: antimony (0,55%; 49,97%), asbestos (2,29%; 94,83%), chromium (0,97%; 73,65%) coal, (7,89%; 11,81%), copper (3,65%; 62,32%), diamonds (4,35%; not available), fluorspar (0,19%; 86,35%), gold (63,94%, not available), iron (1,05%; 55,08%), lead (0,01%; 100%), manganese (2,55%; 83,51%), nickel (1,54%; 85,50%), petroleum (imported), platinum-group metals (5,93%; not available), phosphates (0,62%; 1,03%), silver (0,25%, not available), tin (0,32%, 65,47%), uranium (2,29%, not available), vanadium (1,09%; 87,15%), vermiculite (0,15%; 97,25%) and zinc (0,37%; 62,37%). In dealing with each commodity, the format has been standardised: the general section describes the commodity type, its commercial and industrial utilization and lists the most common mineralisation types and the exploration methodology employed in their search; the second section abstracts, from South African sources, the production, reserves and resources of the relevant commodity; the third section provides its U.S. depletion allowance, prices and import sources together with world production and resources; and the last section condenses domestic and world trends, events and outlooks pertinent to the commodity.

It should be stressed that the condensing of the data into copy of finite length for each commodity in this review, has imposed restrictions on the scope and completeness of the overall study. The study is thus not an in-depth examination of each mineral commodity, nor should it be presumed to be so. Rather it presents a very broad overview and one feels compelled to document the limitations of the data presented as in the following paragraph. Future workers who are interested in the many economic factors that can influence or control a specific ore type, should bear this in mind.

The greater bulk of the data presented originates from published sources for which confidence limits are not always provided. In common with other workers who have dealt with mineral statistics in the past, I have been alarmed at the gross inherent inconsistency of numerical data, such as annual production records, which differ markedly according to each individual source consulted. It is true that many production records are continually updated with better information, but even consecutive volumes show differences in recorded production figures for a given year, without comment on the reason for the changing figures. Discussion with other workers have convinced me that there is no solution to this dilemma. Consequently, in each case figures furnished by government agencies have been preferred from the varied sources consulted. Numerical records of production were avoided where possible and percentage production escalation and growths were adhered to, in an attempt to obviate use of the absolute figures. This unfortunately does not lend any greater confidence to the data, nor is there any method of eliminating inconsistencies in the published data.

Although the author is aware of the confusion that exists regarding conceptual definitions within the complex field of what constitute reserves and resources, and the contrariety and misleading nature of their every-day use, no verification of the validity of published data in this regard was attempted. Furthermore, the establishment of the degree of certainty related to reserve or resource existence was not undertaken and the assessment of the various parameters (location relative to infrastructure and markets; amenability to economic beneficiation; effects of Company and Government policy; political, environmental, social factors; and so on) which determine the feasibility of actual economic exploitability and future-outlook projections, was considered, as has been mentioned above, to be beyond the scope of this report. The standards, terminologies and the enlargement and explanation of abbreviated designations and definitions, are provided in the Appendix.

ANTIMONY

General

Commodity Type

Stibnite (Sb_2S_3) is the most important antimony ore mineral. Of lesser importance are valentinite, Sb_2O_3 ; senarmontite, Sb_2O_3 ; stibiconite, $Sb_2O_4 \cdot H_2O$; berthierite, $FeS \cdot Sb_2S_3$; kermesite, $2Sb_2S_3 \cdot Sb_2O_3$ and bindheimite, $Pb \cdot Sb_2O_7 \cdot nH_2O$. Tetrahedrite, $Cu_8Sb_2S_7$ has become an important antimony ore and some deposits of jamesonite, $Pb_2Sb_3S_5$ have been worked.

Antimony is a brittle silver-white metal with a specific gravity of 6,6 and a melting point of 630,5°C.

Utilization, Substitutes

Antimony is marketed as metal, antimonial lead, antimony oxide and sulphide. Metallic antimony is sold under brand names, each representing metal with a guaranteed antimony content and an allowable maximum of deleterious elements such as arsenic. When used as a metal, its property of expanding on cooling ensures the production of very sharp impressions in castings. Antimony imparts strength, hardness and corrosive resistance to alloys and is an important component of lead and other alloys such as type metal, antifriction metals, fusible alloys and cable coverings. Its most important use is in the manufacture of storage battery plates which contain some 4-6% antimony. Very pure metal is used in inter-metallic compounds for semiconductor and other chemical applications. As a hardening agent, it is used in the manufacture of chemical pumps, tank linings, roofing sheets, plumbing fixtures, foils and bullets. It is also used to make solder, decorative castings of Britannia metal and pewter. "Antimony black" is finely divided metal used in bronzing for metals and plaster casts. Antimony oxides are used as pigments in paints and plastics, as fire-retarding agents and as opacifying agents in ceramics. The sulphides are used in the manufacture of ammunition, smoke generators, range-finding shells, tracer bullets and fireworks and as vulcanising agents in the rubber industry. Matchbox striking surfaces also contain small amounts of antimony sulphide. End-product uses in the U.S.A. during 1975 were transport, 44%; chemicals, 17%; fire retardants, 15%; rubber products, 10%; glass and ceramics, 6% and other, 8%.

Uranium, zinc, chromium, tin and zirconium may substitute for antimony in paints, pigments and enamels. Tin, calcium and dispersion-hardened lead are substitutes for antimony in the hardening of lead. Selected inorganic compounds are acceptable alternate materials in flameproofing.

Geology, Exploration

Antimony occurs in a variety of simple to complex deposits in epithermal veins, in pegmatites and as replacement and hot-spring deposits. It is only lately that the possibility of volcanogenic fumerolic deposits of antimony have been realised. Simple deposits consist principally of stibnite in a siliceous gangue, commonly with pyrite. Associated elements are gold, silver, mercury and arsenic. The "manto" deposits (Mexico) are simple selective replacements in favourable limestone beds. Near surface, the sulphides are oxidized. Complex deposits consist of stibnite associated with pyrite, arsenopyrite, cinnabar and scheelite, or of antimony sulphosalts with base-metal sulphides or important quantities of copper, lead, silver and zinc. Antimony is often a byproduct in the mining of such complex deposits. The deposits of both types range from Precambrian to Quaternary in age.

Exploration methods include geological mapping, especially with a structural bias, and geochemistry, either for antimony as such, or of selected tracer elements associated with known deposits. In many cases the use of mercury "sniffer" methods have proved worthwhile. The effectiveness of geophysical prospecting for antimony deposits remains to be demonstrated but there appears to be no reason why electrical methods (induced polarisation, resistively, self potential) should not be effective if the associated mineral sulphides lend themselves to selective geophysical detection.

SOUTH AFRICA

Sources

The only source is currently from the Murchison range in the North-eastern Transvaal. The deposits occur within a narrow Archaean greenstone belt surrounded by granitic rocks. The ore occurs as lenticular pods within complex dolomitised talcose rocks and quartzites along the so-called Antimony Line. The ores often contain notable quantities of gold. Ore is produced in the form of hand-spalled stibnite cobs or as concentrates containing about 60% Sb. At the Gravelotte property, mining has reached a depth of about 1 100 metres. Minor occurrences of antimony occur on the farm Soodorst and Amo in the Barberton district and antimony was also present as argentiferous tetrahedrite in the Willows silver mine east of Pretoria.

Production

From available records dating back to 1906, South Africa has produced 345 325 tonnes of concentrate up to the end of 1975. Of this 0,26% was produced in 1940 and before; 2,46% from 1941-45; 6,59% from 1945-50; 14,08% from 1951-55; 15,06% from 1956-60; 17,08% (20,09%) from 1961-65; 21,95% (25,01%) from 1966-70 and 22,52% (22,10%) from 1971-75; the figures in parenthesis refer to the RSA share of world production.

Production growth from 1940 was 26,90% per annum made up as follows: 1941-1945, +94,6%; 1946-1950, +29,90%; 1951-1955, +50,94%; 1956-1960, -4,05%; 1961-1965, +11,04%; 1966-1970, +6,11%; 1971-1975, -0,20%. The production may have reached a maintained peak at an average annual production figure of 15 556 ± 886 tonnes of metal. The production in 1975 was 26 160 tonnes of concentrate, up 3,76% from the previous year. The contained metal in the concentrate was 16 000 tonnes.

Reserves, Resources

Estimated mineral reserves are currently (1975) thought to be 350 000 tonnes of metal which is 7,38% of the identified reserves of the world. This figure is probably high since the published life for Consolidated Murchison is 8 years at current production, giving a reserve of 125 000 tonnes of metal (2,64% of world reserves). The overall growth in ore reserves at Consolidated Murchison has been 2,69% per annum since 1955 but these have latterly shown a decline as the following figures indicate: 1955-1950, +6,86%; 1961-1965, +7,25% per annum; 1966-1970, +3,08% per annum and 1971-1975, -6,44% per annum. At current production rate, the life of the antimony reserves is between 8 and 22 years. Resources of antimony in South Africa are thought to be limited.

WORLD

U.S. Depletion Allowance

Domestic, 22%, foreign 14%.

U.S. Prices

Prices have risen at the average of 16,22% per annum since 1958 to the present. The average annual rise for periods illustrates the price fluctuations: 1958-1960, -0,48%; 1961-1965, +8,13%; 1966-1970, +35,26% and 1970-1975, +22,00%. The actual price in 1975 has risen by 5,51 times the 1958 figure. The estimated 1975 price was 175,00 U.S. cents per lb., down 3,72% since the previous year.

U.S.A. Import Sources

Ore and concentrate sources for 1958-1975 were as follows, the tendency rise or fall is shown in parenthesis: R.S.A., 40% (36-51%); Mexico, 34% (46-20%); Bolivia, 17% (14-24-18%); and other, 9% (4-25%). Metal sources (1958-1975) were as follows: United Kingdom, 15,5% (29,0%); Yugoslavia, 35,5% (39-50-14%); Belgium, 14% (20-22-0%); Mexico, 11% (5-17%); others 24% (7-44%). During 1969-1975 the People's Republic of China increased (16-24%) as a supplier of antimony to the U.S.A.

Production

Growth in world mine production has averaged 2,25% per annum during the following years: 1961-1965, +3,68%; 1966-1970, +1,23%; 1971-1975, +1,84%. The present world mine production comes from the following countries (1974): R.S.A., 21,69%; Bolivia, 18,52%; Mexico, 3,41%; Yugoslavia, 2,88%; U.S.A., 0,85%; other free world countries, 23,88%; other communist countries, 28,77%. The other free world countries are Turkey, 6,86%; Thailand, 6,78%; Canada, 2,77%; Morocco, 2,16%; Australia, 1,60%; Italy, 1,37%; and other minor producers, 2,36%. The communist countries (apart from Yugoslavia) are China, 17,41%; U.S.S.R., 10,48%; and Czechoslovakia, 0,88%. The free world (68,35% of production) thus dominates present antimony production. The South Africa production, as a function of world production, appears to fluctuate as follows: 1961-1965, 20,09%; 1966-1970, 24,40%; and 1971-1975, 21,61%. The 1975 world production was estimated to be 73 028 tonnes of metal.

Reserves, Resources

Antimony reserves in 1950 were estimated to be 1 288 200 tonnes of contained metal. In 1973, the identified resources of antimony were 5,08 million tons of metal (China, 67,8%; Bolivia, 7,5%; R.S.A. and U.S.S.R. each 5,3%, as chief contributors) and 14,515 million tonnes as hypothetical resources. In 1975, the reserves were stated to be 4,3 million tonnes of metal to which the following countries contributed: Central Economy Countries, 50,6%; other Market Economy Countries, 23,6%; Bolivia, 8,6%; R.S.A., 7,4% (note reservation above); Mexico, 5,1%; U.S.A., 2,5% and Yugoslavia, 2,2%. Since 1968, the world reserves increased by 8,5%. The utilisation depletion rate in 1975 was 1,64% of world reserves or, stated differently, the world reserves are expected to last some 60 years. Identified world resources in 1975 remained at 5,08 million tonnes.

TRENDS, EVENTS, OUTLOOKS

Domestic

The present value of antimony metal produced in 1975 (16 000 tonnes) is R22 million. About 30% of the sulphide ore produced is presently converted to oxide locally. Unless new discoveries of antimony are made (the present high price of the metal should stimulate exploration) the future production of antimony is probably limited because of falling reserves.

World

The recession made itself felt in the antimony market during mid 1974 and continued through 1975. Consumption decreased and producer metal and ore prices decreased by some 23%, although prices recovered somewhat during the last quarter of 1975, and early 1976. The price decrease caused some stockpiling. Nevertheless the overall U.S. demand for antimony is expected to increase by 4% per annum until 1980. In the U.S.A. and elsewhere, the use of antimony and especially that of antimony trioxide is expected to increase due to escalating demands for flame retardants, for fireproofing and in chemicals. The demand rate in these fields should be higher than the overall demand. Maintenance-free automobile batteries, which use calcium instead of antimony as a hardener, have been developed and were in use during 1976. So far, the impact of these batteries has had little effect on the antimony market. Although the economy slowdown caused a price drop in the U.S.A. from \$2,25 to \$1,60 per lb. during 1975 (in real terms, the drop was 22-24%), the prices rose during 1976 (ore, 8,5%; metal, 16%). The market nevertheless remains unpredictable but the good recovery in the U.S. motor car industry (30% up from 1975) and the anticipated increase in demand for use in flame retardants, augurs well for the future of the antimony industry.

ASBESTOS

General

Commodity Type

Asbestos is a commercial term for naturally fibrous silicates that are amenable to mechanical separation into fine filaments of considerable tensile strength and flexibility, which have characteristic heat-resisting properties. The chief world-wide commodity (93%) is chrysotile ($\text{H}_4\text{Mg}_3\text{Si}_2\text{O}_9$), the fibrous form of serpentine. Crocidolite (Cape and Transvaal blue asbestos) and amosite are fibrous soda- and magnesium-bearing amphiboles. Crocidolite is found chiefly in South Africa while amosite occurrences are specifically confined to South Africa; they respectively make up 3,5% and 2,5% of asbestos commerce. Tremolite (Ca-Mg amphibole), anthophyllite and actinolite are minor, mostly brittle-fibre types. The properties used to evaluate asbestos are flexibility, length of fibre, tensile strength, chemical reactivity, resistance to heat, electrical conductance and filtration characteristics.

Asbestos occurs as cross-fibre veins in which the parallel fibres are orientated either roughly normal to the vein walls or as slip-fibre, in which the fibres lie in a matted to near-parallel arrangement along the plane of the vein; which can also be a plane of movement or "slippage". Mass-fibre shows no preferred orientation of the fibre in the rock and is characteristic of the asbestiform amphiboles, anthophyllite, tremolite and actinolite. The latter types also commonly occur as slip fibre and their general characteristic is to be weak, brittle, and least amenable to separation.

Utilization

Asbestos is a constituent of at least 3 000 manufactured products. About 70% of the world production is used to manufacture a wide variety (shingles, roofing, wallboard, flat and corrugated sheets and piping) of asbestos-cement products and consumption in this sphere appears to be increasing. The remainder of production is used in electrical, heat and noise insulation; in corrosion-resistant binders; as a filler and reinforcing material in rubber and plastics; and as an important component mixed with lubricants in the manufacture of gaskets, packings and clutch and brake linings. It is also spun into yarn and laminated with paper or used as cloth; both being immune to attack by fungus, bacteria or vermin and are not affected by alternate wetting or drying. Asbestos fibres are used as superior inert gas and liquid filters. There appear to be no suitable substitutes for asbestos in its many-faceted uses. The U.S.A. is the chief fabricator of asbestos products and imports some 85% of its raw asbestos for the following end-uses; construction, 70%; floor tiles, 10%; paper products, 7%; transport, 3%; textiles, 2% and other, 2%.

Geology, Exploration

Chrysotile occurs mainly as veins or vein stockworks in serpentinised peridotites, pyroxenites or dunites which are collectively called "serpentinite". It also occurs extensively in favourable dolomitic rocks that have been metamorphosed by basic intrusive dykes or sills. Crocidolite and amosite occur in fine-grained cherty ferruginous metasediments commonly called either banded ironstones or banded iron-formation, which frequently contain bands of these soda-rich minerals. Anthophyllite and tremolite deposits occur in metamorphosed basic intrusions, greenstones, amphibolites and limestones but are of limited and erratic distribution.

Close inspection of ultrabasic bodies located by geological mapping, is usually the method of tracing existing deposits or of exploring for new deposits. Large stockworks of veins within

serpentinised ultramafic igneous rocks are usually the most attractive ore types. Two periods of asbestos formation and serpentinisation are common in peridotitic to pyroxenitic rocks; an initial stage associated with the first cooling of the magma (partial serpentinisation and fibre formation) and a final stage near the end of deformation, where asbestos is associated with shears, faults and fractures (stockworking). Many deposits are flanked by small acidic intrusions which are possibly responsible for the final stockworking and for talc formation, steatisation and carbonation. Since magnetite is produced during serpentinisation, magnetic methods of search and location (ground-based or airborne) are very useful in finding orebodies, especially as magnetite formation often correlates with intense fracturing or faulting. Research needs to be done on discriminating between barren and ore-bearing magnetic anomalies. Since amosite and crocidolite occur with banded iron-formation, their location by magnetic methods should not prove problematical.

SOUTH AFRICA

Sources

Chrysotile occurs only in serpentine rocks derived either from Archaean ultrabasic rocks of greenstone sequences (Barberton) or from dolomites of the Transvaal Supergroup metamorphosed by local intrusions (Carolina, Groblersdal, Pietersburg). Crocidolite and amosite occur together in the banded iron-formation at the top of the Malmani dolomites (Transvaal Supergroup) of the eastern Transvaal (Penge Mine) or in a similar stratigraphic position in the far western basin of Transvaal Supergroup rocks in the Prieska-Kuruman area of the north-western Cape. Tremolite occurs in the Ecca series of the Karoo Supergroup near Pomoroy in Zululand. Anthophyllite has been gleaned intermittently from weathered basic rocks in the Archaean granites of the Soutpansberg.

Production

South Africa's total production of all fibre types from 1941-1975 was 5 548 568 tonnes, made up of: amosite, 36,4%; crocidolite, 40,3%; (Cape blue, 35,6%; Transvaal blue, 4,7%); chrysotile 20,9% and anthophyllite, 2,4%. Small amounts of tremolite have also been produced (1957-1963). Of the total production, 2,6% was produced in 1941-1945; 4,1% in 1946-1950; 9,2% in 1951-1955; 13,5% in 1956-1960; 17,6% in 1961-1965; 23,0% in 1966-1970 and 30,0% in 1971-1975. The average annual growth of production was as follows:

	Amosite	Chrysotile	Cape Blue	Tvl. Blue	All types, total**
1941-1945	+ 7,55*	+ 8,56*	+ 5,86*	+169,50*	+ 1,48
1946-1950	+26,95	+53,27	+13,93	+ 89,41	+29,22
1951-1955	+ 6,95	+11,01	+19,64	- 0,67	+ 8,79
1956-1960	+ 6,92	+ 7,45	+14,75	- 3,54	+ 8,24
1961-1965	+ 3,35	+ 6,22	+12,09	+ 5,35	+ 6,76
1966-1970	+ 6,09	+ 8,75	+ 5,98	- 6,55	+ 5,91
1971-1975	- 1,72	+33,09	+1 452,26	- 11,51	+ 3,93
Weighted average 1941-1975	+ 7,58	+17,85	+217,45	+ 24,88	+ 9,19

* Average growth 3 years 1942-1944

** Including anthophyllite and tremolite

No Transvaal blue asbestos was produced in 1974 and 1975 and a major portion of the drop in amosite production was filled by anthophyllite. Cape blue and chrysotile production both exhibited wide fluctuations.

Reserves, Resources

Identified resources figures from two different sources differ widely. The Geological Survey estimate 7,1 million tonnes of fibre (2,5 million tonnes each of crocidolite and chrysotile and 2,1 million tonnes of amosite) while the Financial Mail (14/2/1975) gives a total figure of 14,0 million tonnes of fibre. The former figure is preferred. Based on the total production figure for 1975 (347 406 tonnes fibre), the total reserves could last from about 20 to 30 years, naturally assuming no production or resources growth during that period.

WORLD

U.S. Depletion Allowance

Domestic, 22-22%; foreign, 10%.

U.S. Prices

Prices showed an average annual growth (1959-1975) of 4,25% with the following fluctuations: 1959-1964, -1,95%; 1965-1969, +1,04% and 1970-1975, +13,66%. The estimated U.S. price per short ton f.o.r. at mine in 1975 was \$182. The f.o.b. value per metric ton based on South African exports were as follows (October-December, 1975): amosite, R322,69 (+66,49%); chrysotile, R142,91 (+1,26%); Cape blue, R423,79 (+83,83%); the figures in parenthesis show the increase from the same quarter in 1974.

U.S.A. Import Sources

For the period 1958-1973, the suppliers were very constant as follows: Canada, 92,70% (rising to 96%); R.S.A., 5,4% (falling 7% to 3%); and other, 1,8% (falling 4% to 1%). Australia and Europe generally supplied the "other" portion.

Production

Growth in world mine production averaged 4,58% per annum during 1961-1975 as follows: 1961-1965, +7,25%; 1966-1970, +2,14% (fluctuating); 1971-1974, +4,37%. For the ten years period 1964-1974, South Africa's contribution to world production was 7,84 ± 0,85%. In 1975 the chief asbestos producers were U.S.S.R., 36,4%; Canada, 29,2%; R.S.A., 9,5%; Rhodesia, 6,4%; Italy, 4,0%; West Germany, 2,7%; U.S.A., 2,4% and others (Brazil, Australia, Swaziland, Cyprus, Japan etc.) 9,4%. World production in 1975 reached 3 734 million tonnes of fibre, with the free world producing some 60% of that total.

Reserves, Resources

From 1963-1973 the world reserve estimates trebled to 298,46 million tonnes of fibre. The South African reserves made up 7% of that total. A re-assessment of the reserves in 1975 led to a drastic 70,8% reduction of the world reserves. World reserves and identified resources stood at 87,09 million tonnes in 1975, to which the following countries contributed: Canada, 42,7%; Central Economy Countries, 32,3%; other Market Economy Countries, 14,6%; R.S.A., 6,2% and the U.S.A., 4,2%. World hypothetical resources of fibre are 48 million tonnes. The current resources depletion rate (1975) is 4,29%, or an identified resources life of 23 years. The only known source of amosite is from South Africa. The bulk of the crocidolite (blue) asbestos also occurs in South Africa and hopes of Australian production have been somewhat dampened by poor resource estimates (submarginal resources, 2 million tonnes).

TRENDS, EVENTS, OUTLOOKS

The longstanding dominance of Canada in the free world trade, production and milling of chrysotile have also assured that she sets the specification standards that affect asbestos commerce and industry, with which outside producers must comply to be viable. On the same basis, South Africa calls the tune, especially regarding pricing, of the amosite and crocidolite markets.

The wide range of asbestos products gives an end-use market spread which, combined with a wide geographical spread, cushions demand fluctuations. Nevertheless the high proportion of use in the construction and automotive industries means that asbestos demand can be varied by the activity within those industries. The fact that demand has continued to exceed supply in those industries during the early periods of recession, is a bright aspect of asbestos marketing. Demand in 1975 was 5 times the demand in 1925 and about 1½ times the demand in 1950.

The world-wide recession in the building, automotive and shipping industries during 1975, adversely affected the asbestos market. The supply of chrysotile was further hampered by the strike at the Thetford mines in Canada which lasted from March to October and other producers were only partly successful in countering the production shortfall caused by that strike. Asbestos of almost all grades continued to be in short supply throughout 1975. The fact that demand has exceeded supply during the early recession augered well for the short-term future and has stimulated exploration and expansion in Canada, Russia, Greece and Brazil. South Africa would do well to investigate new sources of all asbestos types although the continuing slump in the building and automotive industries could well cause oversupply and consequent shut-down of both domestic and overseas mines and this would consequently limit the scope of exploration for new resources.

CHROMIUM

General

Commodity Type

The mineral chromite ($(\text{Mg}, \text{Fe}^{+2}) (\text{Cr}, \text{Al}, \text{Fe}^{+3})_2\text{O}_4$) is the only commercial source of chromium metal and varies compositionally within the wide limits permitted by its chemical formula. The pure mineral ranges from 15-64% Cr_2O_3 but useable ores which are mixtures of chromite and silicate minerals, range from 33-55% Cr_2O_3 . Three ore types are recognised from the following compositions: (1) Metallurgical ore, high grade over 46% Cr_2O_3 and $\text{Cr}/\text{Fe} = 2:1$ or more; (2) Chemical-grade ore, high-iron with 40-46% Cr_2O_3 and Cr/Fe less than 2:1; and (3) Refractory ore, high-alumina, over 20% Al_2O_3 with more than 60% Al_2O_3 and Cr_2O_3 combined. The high-iron ores are used primarily for producing chemicals but also in alloy and refractory production. The chemical industry accepts friable ores but the metallurgical and refractory industries prefer hard lumpy ores.

Utilization

As noted above, three grades of ore (metallurgical, chemical, refractory) are produced. Some 67% of the world production is used metallurgically especially in ferrochrome production for the steel industry. Metallurgical chromite is used in the production of stainless and alloy steels and for electroplating. In the production of refractories, 18% of the chromite is used with magnesite as a binding agent. The chemical industry produces chromate and dichromate from which nearly all other chromium chemicals are derived, thereby using about 15% of chromite produced. Secondary uses include: construction, 22%; transport, 16%; refractories, 14-17%; industrial machinery and equipment, 14-15% and all other, 30-34% in the U.S.A. during 1975.

Geology, Exploration

Primary chromite deposits occur within specific types of ultramafic or differentiated mafic rocks with closely related norites, anorthositic norites or anorthosites. The deposits are of two major types; layered-stratiform and pod-shaped. The first type occurs in the lower portion of differentiated layered igneous complexes and is characterised by great lateral extent and uniformity and by consistent positions within the stratigraphy of its host complex. This type contains more than 98% of the chromite resources of the world. The podiform chromites are rudely tabular to lenticular bodies although some defy description as to form. They range in size from mere inclusions up to masses of several million tonnes. They occur in irregular peridotite or peridotite-gabbro complexes in high-grade metamorphic terrains and commonly show the considerable tectonic affects of their environment such as stretch and disruption. Erosion of primary chromite deposits may give rise to secondary deposits as black sands or lateritic soils.

Layered complexes should be well-mapped and physically prospected (trenching, pitting, drilling) for stratiform chromite seams. Geochemical methods have no application in chromite prospecting but airborne magnetics and ground gravity surveys have applications for locating deposits within covered host rocks. The relatively low price of the commodity would discourage expensive exploration and prospecting methods.

SOUTH AFRICA

Sources

The entire South African production stems from chromite seams in the Bushveld Complex of the central Transvaal and consists almost entirely of high-iron chromite. The 14 to 16 seams occur within the Critical Zone below the Merensky Reef of the Bushveld Complex. Some of the seams are traceable over scores of kilometres, being individually almost uncanny in their lateral persistence, in their mode of occurrence, thickness, chromium content and mineral association. The seams have been traced intermittently over a distance of some 117 kilometres in the eastern lobe, and some 160 kilometres in the western lobe of the Complex. The seams show an increasing grade and Cr/Fe ratio downwards. The seams have been grouped as follows: (1) Lower Group, consisting of at least seven seams; (2) the Middle Group, of at least 4 seams and (3) an Upper Group, of usually 2 but often 3 seams. Their characteristics are as follows :

Group of Seams	Cr ₂ O ₃ %	FeO% *	MgO%	Al ₂ O ₃ %	Cr/Fe
Upper	43,7 ± 0,1	29,3 ± 0,8	8,8 ± 0,7	15,5 ± 1,2	1,31 ± 0,05
Middle	44,4 ± 0,7	27,5 ± 0,9	8,9 ± 0,3	16,9 ± 0,7	1,41 ± 0,06
Upper Lower (3 seams)	46,4 ± 0,6	26,1 ± 0,6	9,9 ± 0,5	15,3 ± 0,6	1,56 ± 0,05
Lower (4 seams)	50,7 ± 0,9	22,8 ± 1,2	11,6 ± 1,4	12,8 ± 1,1	1,94 ± 0,15

* Total iron as FeO.

Other occurrences of note are those in the Goudini compartments of the Complex north of Zeerust, and in the Drummondlea area south of Potgietersrus, both of which are high-grade ores with a high Cr/Fe ratio.

Production

South Africa has produced 27 722 013 tonnes of chromite ore from 1941-1975. The following listing gives the percentage of ore produced during five-year periods and, in parenthesis, the average annual production growth for the same five-year period: 1941-1945, 3,6% (-13,13%); 1946-1950, 6,9% (+43,97%); 1951-1955, 10,9% (+2,83%); 1956-1960, 11,5% (+2,17%); 1961-1965, 15,9% (+11,87%); 1966-1970, 20,3% (+2,92%) and 1970-1975, 30,9% (+14,81%). The average annual growth in production (1941-1975) has been 9,35%.

During 1939-1956 the average ore grade was 44,79% Cr₂O₃. From 1953-1975, the ore grades produced were as follows: -44% Cr₂O₃, 36%; 44-48% Cr₂O₃, 60%; +48% Cr₂O₃, 4%.

Reserves

South Africa is the largest free-world source of chemical grade chromite. In 1950, the reserves were stated to be 100 million tonnes of chemical (high-iron) ore and 2 million tonnes of low-grade metallurgical ore suitable for blending. In 1973 the estimated position was as follows: Reserves: metallurgical, 50,8 million tonnes and chemical 1 016 million tonnes; conditional resources: metallurgical 50,8 million tonnes and chemical 2 032 million tonnes; hypothetical and speculative resources +3 048 million tonnes.

Cousins and Feringa (1964) estimated the total Bushveld (east and west lobes only) chromite resources to be 18 000 million tonnes to about 1 500 metres vertical depth. Because of the extraction difficulties at that depth, this is probably an over-estimate. A proportionate figure is 3 543 million tonnes to 300 metres vertical depth. This shows better agreement with the identified resources of 3 100 million tonnes (to unknown depth) quoted above.

A recent estimate (recalculated from Von Gruenewaldt, 1976) showed the following: +50% Cr₂O₃ ore: average grade, 52,7% Cr₂O₃, average Cr/Fe = 2,13, average thickness 53,2 cm over 74 kilometre strike to a vertical depth of 300 metres, 176,6 million tonnes; 45-50% Cr₂O₃; average grade 46,3% Cr₂O₃, average Cr/Fe = 1,58, average thickness, 113,5 cm over 215 kilometre strike to a vertical depth of 300 metres, 1 350 million tonnes; ore with Cr/Fe of ± 1,45: average grade 44,1% Cr₂O₃, average Cr/Fe = 1,44, average thickness 150,7 cms over 75 kilometre strike to a vertical depth of 300 metres, 806 million tonnes. This gives a total of 2 332,6 million tonnes with an average grade of 46,3% Cr₂O₃, an average Cr/Fe = 1,6, an average thickness of 109 cms over a total strike length of 364 kilometres to 300 metres depth. Using this total reserve figure, at the 1975 production rate (2 075 378 tonnes) the reserves will last for 1 124 years (current depletion rate, 0,09%).

The grade of the ores is naturally important. The total average thickness of chromite contained in the various seams of the Western Bushveld is 9,92 metres which gives a weighted average grade as follows: Cr₂O₃, 45,3%; FeO, 27,0%; MgO, 9,3% and Al₂O₃, 15,8% with a Cr/Fe ratio of 1,48 which is probably a good average Bushveld grade (see production above). Based on total thickness of chromite in the seams, the grades are as follows: low-grade (-44% Cr₂O₃, Cr/Fe = 1,31) 25,65%; chemical grade (average 45,4% Cr₂O₃, Cr/Fe = 1,48) 68,59% and metallurgical grade (average 51,5% Cr₂O₃, Cr/Fe = 2,1) 5,76%. Since seams less than 0,5 metre in thickness are probably presently uneconomic to mine, disregarding them gives a total thickness of 8,60 metres of which low grade constitutes 27,4% and the remainder is chemical grade (average 45,0% Cr₂O₃, Cr/Fe = 1,46).

WORLD

U.S. Depletion Allowance

Domestic, 23%; foreign, 15%.

U.S. Prices

The U.S.A. price (long ton dry basis, f.o.b., Atlantic Ports) for Transvaal +44% Cr₂O₃ (no ratio) ore rose by an average of 7,97% per annum from 1964-1975. The price appears to have been fixed over long periods but showed a major increase from 1971-1975 by 15,8% per annum. The price for 1975 was estimated at \$45,00 per ton, showing a rise of 32,35% over the 1974 price of \$34 per ton.

U.S. Import Sources

Ore sources are as follows (1962-1974) with trends shown in brackets: R.S.A., 36,7% (44-29%); U.S.S.R. 19,8% (9-32%); Phillipines, 16,6% (22-14%); Rhodesia, 10,8% (24-0%); Turkey, 7,8% (0-18%) and other, 8,3% (2-13-8%). In 1974, South Africa supplied 35% of the U.S. ferrochrome imports.

Production

World production of chromite ore rose by 3,73% per annum from 1961 to 1975 as follows: 1961-1965, +3,41% (20,2%); 1966-1970, +5,18% (24,2%) and 1971-1975, +2,60% (24,8%). The figures in brackets refer to the average South African share in world production. In 1974, world production amounted to 7,195 million tonnes made up as follows: Central Economy Countries, 36,6%; R.S.A., 26,1%; other Market Economy Countries, 14,8%; Rhodesia, 8,2%; Phillipines, 7,4% and Turkey, 6,9%.

Reserves, Resources

According to some sources, world chromite reserves have dropped by 36% from 1963 to 1975. This is almost certain to be because of original over-estimation rather than by production-depletion. World reserves in 1973 (in millions of tonnes) were estimated as follows:

<u>Identified Resources</u>			
	<u>Reserves</u>	<u>Conditional Reserves</u>	<u>Hypothetical, speculative</u>
>46% Cr ₂ O ₃			
Cr:Fe 2	586,513	583,770)
40-46% Cr ₂ O ₃			
Cr:Fe 1,5-2	1 081,074	2 062,575)
40% Cr ₂ O ₃	1,016	2,032	
Al ₂ O ₃ + Cr ₂ O ₃			
60%	14,275	12,243)
	1 682,878	2 660,620	3 638,718

The world identified resources are distributed as follows: South Africa, 71,5%; Rhodesia, 25,4%; U.S.S.R., 1,0% and other 2,1%.

TRENDS, EVENTS, OUTLOOKS

Domestic

With her enormous chromite reserves, the chrome position in South Africa appears to be very bright. In 1975 she produced just over 2 million tonnes of ore valued at almost R41 million. It has been estimated that production will reach 3,6 million tonnes in 1980 and, at an average annual growth of 5% until the year 2 000, the production will be 9,6 million tonnes (worth almost R200 million at today's prices). Of this 4,9 million tonnes will be used by the local ferrochrome industry leaving the balance either for export or to satisfy local chemical and foundry demand (300 000 tonnes). At today's prices the exports should be worth about R90 million. The trend in South Africa is to utilise the immense chrome resources to produce ferrochrome. Thus ferrochrome producers are already operating and new plants at Steelpoort (General Mining, Union Carbide) and at Lydenburg (J.C.I., Anglo American and others) are respectively expected to commence production in the last quarter of 1976 and in 1977. It is thus estimated that the 1975 ferrochrome production of 250 000 tonnes will have increased to 800 000 tonnes in 1980 when the new plants are producing at full capacity. Thereafter a 5% annual cumulative growth has been forecast, on which basis, production in 2000 will be 2,1 million tonnes, valued at R1 600 (1976 rand).

World

The world-wide recession in 1975 was reflected by a weakening demand for all categories of chromite. In the U.S. demand dropped to 1971 levels after establishing a record high in 1974 and consumption fell sharply - metallurgical grade ore by 42%, refractory ore by 36% and chemical ore by 32%. Nevertheless U.S. imports of chromite (+422,5%) and chromium alloys (+71,6%) improved considerably so that consumer stocks increased substantially. The U.S. stockpile reported large excesses (80,52% of stocks of chromite, 98,54% of ferroalloys). Although the immediate onlook for chromite producers is clouded by these high stocks and weak demand, U.S. demand forecasts estimate a 2,1% per annum growth for primary chromium until 1980. Short- and long-term forecasts must depend on stock depletion rates and the state of the economy in general. International relations, including sanctions, will influence the supply/demand position for the future, as they have done in the past.

COAL

General

Commodity Type

Although coal is commonly classed as a mineral, it differs from the broad definition of minerals which are natural inorganic elements or compounds with a defined chemical composition. Coal is of organic origin resulting from the decay of plant material in swampy areas that were transformed and metamorphosed over millions of years into various types of coal emanating from the same starting material. Coal, like wood and peat, contains carbon, hydrogen, oxygen, nitrogen, sulphur and a host of trace element constituents. Classification of coal is based on their nature and chemical composition which depends on the nature of the original plant material and its admixture with sand, silt or mud, and its subsequent transformation and metamorphism by geological processes through the ages. Type describes the appearance of the coal (dull, bright) and rank defines the maturity of the coalification process and its metamorphism. In order of increasing rank coals are classified as lignitic, sub-bituminous, bituminous (coking and non-coking) and anthracitic in which carbon and calorific value increase while oxygen, hydrogen, volatiles, moisture, chemical reactivity and friability decrease.

Moisture, sulphur and ash are the undesirable ingredients of coal while volatile matter and fixed carbon are the most important contributors to the energy produced when coal is burned. Consequently proximate analyses determine moisture content, the amount and nature of ash, volatile and fixed carbon contents. Ultimate analyses determine the carbon and hydrogen found in the gaseous products of combustion, sulphur, nitrogen and ash in the material as a whole and the estimation of oxygen by difference. The calorific or heating value of coals is determined separately.

Utilization

Of all the fossil-fuel sources of energy, coal is the most abundant. Most of the coal produced is burned for heat and power production, or carbonised to produce metallurgical coke. Although there are many other uses of coal (gasification, hydrogenation etc.) these are of relatively minor importance in terms of the large tonnage in the actual present utilization scheme. Potentially important new uses of coal are constantly being developed. Most coal produced today is used to generate electricity (U.S.A. 1973, 62%, 1975, 72%; R.S.A., 1968, 52,7%), provide process heat and heat for domestic use. The second largest use is in the steel industry (U.S.A. 20%) to produce coke and, as byproducts of the carbonisation process, coal chemicals. About 1,5 tons of coal produces 1 ton of coke which, in turn, is required to make about 1,25 to 1,5 tons of pig iron. Coal tar and light oils produced by carbonisation serve as raw materials for organic chemicals like synthetic rubber, detergents, plastics, photographic materials, flavour and perfume chemicals, explosives, medicines, wood preservatives, disinfectants, animal dips and road and building materials. Similarly coke has been the source of water gas, a mixture mainly of adjustable hydrogen and carbon monoxide. The hydrogen can be used in ammonia synthesis, for hydrogenation of oils to produce margarine and cooking fat and to convert coal to chemicals and liquid fuels. Coal ash products (fly ash, flue dust, coal ash, cinders etc.) may be used as a raw material in cinder blocks, in cement and concrete products and road construction. Flue dust and coal ash may become an important source of byproduct trace elements (germanium, vanadium, lithium, uranium), major elements (alumina, sulphur) or other chemicals. In 1975, other uses, excluding electricity and steel, included: coke plants, 15%; manufacturing, 12% and retail, 1%. Apart from electricity generation, R.S.A. utilization in 1968 included: railways, 11,9%; industry, 11,1%; coke production, 10,8%; domestic, 6,4%; Sasol, 3,6%; mining, 2,8% and coal-gas production, 0,7%. In 1968, coal and coal products accounted for 79,5% of South Africa's energy budget.

Geology, Exploration

By the nature of its accumulation within swampy areas, coal is always associated with suitable basin structures in post-Silurian sediments up to 200 million years in age. The heavy growth of trees,

ferns and other plants in bogs and swamps grew and fell century after century, accumulating *in situ*, and being buried to a gradually increasing depth each year by new accumulations. In the northern hemisphere the environment was a mild to tropical climate but the climate in the southern hemisphere was cold and the accumulation environment was in tundra-like swamps. The plant remains changed gradually to peat and plant growth was terminated by sedimentary burial as a result of transgressive seas. The burial caused the oxygen supply to be cut off, so that rapid decay of the organic matter was prevented by slow bacterial action. The weight of incumbent sedimentation compressed and solidified the coal, although this coalification process was extremely slow. This sequence was repeated in time, depending on a very delicate balance between oceanic regression or transgression, uplift of the hinterland, subsidence of the basin, the duration of the peat-forming cycles in the swamps and their eventual covering by suitable sediments. Earth movements eventually generated the heat, pressure and shearing forces necessary to produce high-rank coals in some areas.

Coal exploration relies greatly on geological compilation, especially of borehole information and on geological mapping, to determine the structure of the sediments associated with coal-bearing measures. There is no geochemical application to coal search and geophysical methods have been limited to tracing dykes, sills or faults that could affect the coal-bearing formations.

SOUTH AFRICA

Sources

All the coal in South Africa occurs within the Karoo Supergroup. Three of the four Karoo subdivisions are coal-bearing and only the lower glacial Dwyka Group is barren. The succeeding Ecca Group (Lower Permian) contains the most important deposits, the middle Ecca often being referred to as "the coal measures". The succeeding Beaufort and Stormberg Groups contain low-grade coal seams but these are largely unexploited at present. Although the platform on which coal occurs is of truly enormous extent, it must be stressed that conditions were not always favourable for coal to be formed and large gaps occur in the continuity of coal-bearing measures.

The most important producers of coal are located in the Vereeniging area, the Springs-Heidelberg-Nigel area, the Witbank-Middelburg-Hendrina-Bethal area, and the Breyten-Ermelo-Carolina area of the Transvaal, and the Dundee-Newcastle and Utrecht-Vryheid areas of Natal. Largely unknown fields in the Transvaal are located in the Wakkerstroom-Piet Retief area, the Warmbaths-Waterberg area, the Zoutpansberg area and the Lebombo-Komatipoort area. The Orange Free State is an extensive unexplored field. Coal in the Molteno-Indwe area of the north-eastern Cape has not proved economic.

Production

From 1941-1975, South Africa produced 1 334 212 million tonnes of coal as follows: 1941-1945, 7,8%; 1946-1950, 9,1%; 1951-1955, 10,6%; 1956-1960, 13,5%; 1961-1965, 16,2%; 1966-1970, 19,2% and 1971-1975, 23,6%. The production growth for the same period has averaged 4,02% per annum as follows: 1941-1945, +6,18%; 1946-1950, +2,42%; 1951-1955, +3,64%; 1956-1960, +3,56%; 1961-1965, +4,90%; 1966-1971, +2,47% and 1971-1975, +4,96%. The 1975 production was 69 439 598 metric tonnes of coal.

Reserves

Estimates of South African coal reserves (all types) have been undertaken at various times and the results are shown below:

Date	Source	Reserve, millions of tonnes	Note
1928	Wyberg, no qualification	226 700	
1952	Venter, <i>in situ</i>	74 872	
1959	Mineral Resources. No qualification	79 882	
1969	Van Rensburg et al.		
	<i>In situ</i> Reserves.	26 503,5	Resources 11 325,4
	Potential Reserves.	37 351,0	
	Total	63 854,5	Total 75 179,9
1975	Petrick et al.		
	Resources, mineable	32 223	
	<i>In situ</i> , bituminous only.	26 027	
	Indicated	23 274	
	Inferred	81 524	

Assuming resources of 80 000 million tonnes and a depletion rate equal to the 1975 production, the life of domestic reserves is over 1 000 years.

WORLD

Depletion Allowance

U.S. domestic, 10%; U.S. foreign, 10%.

U.S. Prices

Prices for bituminous coal and lignite (f.o.b. mines) trended as follows: 1961-1965, -1,08%; 1966-1970, +4,93%; 1971-1975, +25,99% giving an overall annual rise of 9,95%. The estimated overall price in 1975 was estimated at \$18,75 per ton, representing a 19,05% rise since the previous year.

U.S. Import Sources

(1970-1973) the suppliers were West Germany, 31%; Canada, 28%; Poland, 25%; South Africa, 8% and other, 8%.

Production

World production rose as follows: 1961-1965, +1,46%; 1966-1970, +1,30%; 1971-1974, +8,99% giving an annual trend of 3,92% which is very similar to that in South Africa. The 1974 world production figure was 2 942,5047 million tonnes to which the following countries contributed: Central Economy Countries, 57,7%; U.S.A., 18,6%; West Germany, 7,3%; U.K., 3,6%; Australia, 3,1%; India, 2,9%; other Market Economy Countries, 2,3%; R.S.A., 2,2%; Canada, Japan and France each 0,7% and Belgium, 0,2%.

Reserves, Resources

The world resources in 1974 were 11 421 156 million tonnes, having shown an average annual drop of 0,14% since 1963. The world coal resources appear adequate for 3 880 years at the rate of present annual production. The resources in main countries are as follows: Central Economy Countries, 59,8%; U.S.A., 31,5%; West Germany, 2,5%; Australia, 1,7%; Canada, 0,95%; other Market Economy Countries, 0,9% and other, 2,65%. South Africa's resources only rate about 0,4% of the world resources although the survey used places the resources at only 54,5% of what has been estimated internally.

TRENDS, EVENTS, OUTLOOKS

Domestic

Due to its lack of mineral oils, South Africa leads the field in plants designed to convert coal into liquid fuels and oils by the Fischer-Tropsch process on a substantial scale. Thus the first Sasol synthetic-fuel plant was established 20 years ago at a capitalisation of R300 million; the plant uses 18 000 tons of coal daily from reserves estimated to last for 100 years. However, the coal market, its utilization and export patterns were profoundly affected by the 1973 energy crisis. The following table shows a projection of consumption before the energy crisis (millions of tons).

Year	Electricity Generation	Railways	Coke Producers	Coal Gas	Mining	Sasol	Industry	Domestic	Total
1968	28,66	6,46	5,86	0,37	1,50	1,97	6,02	3,49	54,33
1980	35,24	1,98	12,20	0,53	1,64	1,97	5,89	4,02	63,47
2000	83,34	0,11	33,50	1,41	2,57	1,97	11,79	2,94	137,63

The energy crisis materially hastened the establishment of a second synthetic-fuel plant (Sasol II) at Trichardt in the eastern Transvaal due to be completed at a capitalisation of R1 000 million by 1981. Its consumption rate will be 40 000 tons of coal per day and it will reputedly produce about ten times the amount of fuel oil of the current operation, which will increase its annual consumption of coal from 5 million tonnes of coal at present to 20 million tonnes by 1985. The export market has also been affected by the energy crisis and it appears unlikely that further contracts for coking coal will be

entered into but internal forecasts of coal consumption for coke production remains at 33 million tonnes by the year 2000. Current projections for coal consumption for electricity generation by ESCOM during the year 2000 is expected to be 120 million tonnes per annum which takes into account a 22% nuclear generating capacity at that time. Provisional quotes for the export of 800 million tonnes of our low-cost, low-sulphur steam coals have been granted but it is questionable whether the Richards Bay rail link (capacity 21 million tonnes per annum) or the port facilities are capable of handling that tonnage. In addition, industrial, domestic and other consumers are now expected to consume 43 million tonnes of coal in the year 2000 when total production is projected to be between 230-255 million tonnes depending on whether exports amount to 15 or 40 million tonnes. This represents an annual growth rate of about 5,5% from the 1975 production of 69,5 million tonnes. (Local sales R278,78 million; exports R37,35 million). Hit by the world inflation malaise and spiralling wages cost, the price of coal has risen appreciably over the past few years and will probably have the effect of moving domestic mining away from the current inexpensive but wasteful room and pillar methods to alternative high-recovery methods.

World

The very substantial increases in coal output recorded by almost every major producer (average about 4%) during 1975 was indicative of the increasing importance of coal in the overall energy picture. This represents an annual growth rate of more than twice that achieved over the past decade and offers hope that the industry will be capable of meeting future demands made upon it. Depending on the overall economic situation, the future of coal appears to be ensured.

COPPER

General

Commodity Type

Copper is found either as the rare native metal in nature or as the sulphides chalcocite (Cu_2S), chalcopyrite ($Cu.FeS_2$), covellite (CuS) and bornite (Cu_5FeS_4); as the oxide cuprite (CuO_2); as the carbonates malachite and azurite or as the silicate chrysocolla. Copper is one of the most useful and versatile of metals and has been used by man for a longer period than any other metal except gold. Commercial copper is classified broadly into electrolytic or fire-refined types depending on the refining method. Resulting from the high affinity of molten copper for oxygen, the three basic types of commercial copper are designated as tough-pitch copper (electrolytic or fire-refined copper with a controlled quantity of oxygen), oxygen-free copper (cage under deoxidizing atmosphere, eliminating oxygen without metallic or metalloid deoxidizers) or deoxidized copper (utilization of metallic or metalloid deoxidizers). Conductivity standards grade copper into high-conductivity, casting, phosphorized, arsenical, silver- and tellurium-bearing types. Shapes depend on the end use of copper such as wire bar, cake, billet, ingots and ingot bar and are produced into the following fabricators products: wire, tube, pipe, rod and flat product.

Utilization

The properties of copper, namely the high electrical and thermal conductivity, good erosion resistance, good ductility and malleability, high strength, lack of magnetism and a pleasing reddish colour, render it a most useful metal with innumerable industrial applications. Copper and many of its alloys can be joined by welding, brazing or soldering and they can be finished by plating or laquering. The four traditional copper-based alloys (40% Cu) are brass, bronze, nickel-silver and cupro-nickel but copper is a more minor constituent of many alloys. About half (52%) of copper is used in electrical applications in the U.S.A. followed by construction, 17%; industrial machinery, 14%; transportation, 10%; in ordnance, 2% and miscellaneous, 5%. Aluminium is substituting for copper especially because of its lightness - so that whereas aluminium consumption has tripled in the last two decades, copper consumption has only risen 15%. Copper is traded in ore, concentrate, matte, blister, refined and secondary, all with varying copper contents.

Geology, Exploration

The exceedingly bright colours of copper minerals in the oxidized zone have always been a guide to copper prospecting through the centuries. The copper deposits of the world are currently classified into five major types: (1) porphyry copper and vein and replacement deposits, with a common genetic association with felsic intrusive rocks which are dependent on their tectonic environment; (2) strata-bound deposits formed by chemical or biological processes in sedimentary rocks (i.e. Copper belt, Kupferschiefer, Red-bed copper deposits etc.); (3) as massive sulphide deposits in basaltic and andesitic volcanic rocks and tuffs (Cyprus, Kuroko type of Japan etc.); (4) copper in nickel ores formed by magmatic processes in mafic intrusives (Bushveld Complex etc.) and (5) native copper ores in amygdaloidal lavas (Keweenawan type). It is of interest to note that modern technology has

decreased the grade of copper ores exploited considerably since the turn of this century. In 1910 the average grade worked was 4,0% Cu, in 1940 it was 1,20% Cu, in 1950 it was 0,89% Cu, in 1960 it was 0,73% Cu and in 1970 it was 0,60% Cu. No later figures are available but the grade may have dropped further still.

It must be assumed that most easily locateable copper deposits have already been found and that continued reliance will have to be placed on indirect search methods. Except for the leached soils of high-rainfall areas, soil geochemistry is a very satisfactory method for locating copper either on high- or low-density searches. The same applies to stream-sediment sampling as a low-density reconnaissance method. Refinements of geochemical methods and improved statistical data processing including computerisation, are continually taking place. Cheaper and rapid analytical methods have made the analysis of large number of samples feasible on a multi-element basis.

Other methods of regional search are largely photographic. Only in desert areas, have colour anomalies ("red thumbs") indicated copper orebodies, but photogrammetric and satellite-image interpretations are the tools of the future for localising anomalous areas of alteration or favourable structures for copper mineralisation.

Geophysical methods of many types are suitable for copper prospecting although they are employed more during evaluation rather than during search. The choice of methods is usually specific to certain ore types. Recent developments in geochemistry and geophysics have made the recovery of more information from diamond drilling possible, rather than simply the geology and copper assays from the core.

SOUTH AFRICA

Sources

The chief producers of copper in South Africa are the mines at Phalaborwa, Messina, O'Okiep and Prieska (Copperton). These are chiefly associated with intrusive rocks (carbonatite at Palabora, "noritoid" bodies at O'Okiep) or as hydrothermal veins or replacement in brecciated rocks (Messina) or as possible volcanogenic deposits (Prieska). Copper is recovered as a byproduct of the mining of the Merensky Reef (see Platinum) in the Bushveld Complex. A host of smaller and largely unexploited deposits of varying type are on record in South Africa but their potential is probably limited.

Production

Ore and concentrate production of largely unknown grade but probably representing mostly relatively high-grade copper, was 2 498 280 tonnes from 1941 to 1975 as follows: 1941-1945, 5,0%; 1946-1950, 6,2%; 1951-1955, 7,7%; 1956-1960, 9,6%; 1961-1965, 11,0%; 1966-1970, 26,2%; 1971-1975, 34,3%. The average percentage growth rate in production for the same period was 8,28% per annum as follows: 1941-1945, +7,73%; 1946-1950, +6,71%; 1951-1955, +7,74%; 1956-1960, +0,79%; 1961-1965, +6,12%; 1966-1970, +25,14% and 1971-1975, +3,76%. In 1975, the copper concentrate production was 197 233 tonnes, the pure metal content of which is about 2,6% of world total production (assuming 88,72% Cu, 175 000 tonnes pure metal).

Reserves

Prior to 1963, O'Okiep and Messina accounted for all of the South African reserves of copper. Their blocked out reserves, in terms of copper metal during the years 1954 to 1971 showed a decrease in the case of O'Okiep (-0,46% per annum) and an increase in the case of Messina (+18,37% per annum) on available information. In 1963 Palabora had been assessed (315 million tonnes of ore at 0,69% Cu assuming a 0,3% cut-off, i.e. 2 173 million tonnes of copper metal) and was soon followed by the discovery of Copperton and Aggeneys in the north-western Cape Province. The identified resources which are shown in the following table are probably low since Palabora is now proceeding towards a depth of 500 metres which would hike the copper metal resources to 5,302 million tonnes which, when compared with the 507 248 tonnes of metal as blocked out reserves in 1954 (O'Okiep and Messina), represents a rise of 10,45 times. A conditional but nevertheless demonstrable resource of 9,95 million tonnes of copper metal is contained in the Bushveld Complex (see Platinum) to a depth of 1 200 metres vertical depth, but seeing as it is a byproduct to platinum mining on which its extraction is based, it must be regarded as a conditional resource. The total South African resources of at least 15 252 million tonnes are about 3,74% of 1975 world resources and at the current rate of production, will probably last for 75 years.

Area	Millions Ore Tonnes	Average Grade	Copper Metal Tonnes
Messina (1973)A	5 461	1,437%	78 500
O'Okiep (1973)A	25 436	1,565%	398 000
Palabora (1971)B	315 000	0,069%	2 173 500
Prieska (1972)C	47 000	1,737%	816 000
Black Mountain (1974)D	N.A.	N.A.	564 000
Broken Hill (1975)D	N.A.	N.A.	272 000
TOTAL	-	-	4 302 000

A = blocked out reserves; B = demonstrated resources to 300 metres;
C = demonstrated resources to 900 metres; D = demonstrated resources.

WORLD

U.S. Depletion Allowance

Domestic, 15%; foreign, 14% (1961-1975).

U.S. Prices

The prices showed an average annual increase of 5,78% from 1961 to 1975 as follows: 1961-1965, +2,09%; 1966-1970, +10,12%; 1971-1975 (widely fluctuating) +5,14%. The price trend in 1974/1975 is a drop of some 30-40% to an average estimated price of 53,6c per lb. in 1975. Nevertheless the fluctuating 1975 LME prices showed an overall gain of 3%.

U.S. Import Sources

Supplies to the U.S.A. (1958-1974) were as follows, with trends shown in parenthesis: Chile, 33,2% (43-17%); Canada, 23,1% (19-33%); Peru, 20,3% (12-22%); South Africa, 6,1% (6-8-6%); and other, 17,3% (variable).

Production

From 1961-1975, worldwide production has grown at an average rate of 3,42% as follows: 1961-1965, +3,66%; 1966-1970, +3,48% and 1970-1975, +3,11%, thus showing a small overall decline. The 1975 production of 6,624 million tonnes showed a 9,95% drop from the previous year thus maintaining the declining tendency of the year previous to 1974. The 1974 mine production came from the following countries: U.S.A., 19,7%; Chile, 12,3%; Canada, 11,4%; U.S.S.R., 10,1%; Zambia, 9,5%; Zaire, 6,8%; Australia, 3,5%; Phillipines, 3,1%; Peru, 3,0% and other 20,6%. During 1974, South Africa produced 2,7% of the world total output.

Reserves, Resources

About 67% of the world resources are contained in replacement and vein deposits of which porphyry coppers constitute the most important source, 25% is contained in sedimentary rocks, 5% as massive sulphide deposits in volcanic rocks, and the rest within nickel/copper ores or as native copper of Keweenawan-type deposits.

World copper reserves showed the following annual growth: 1940-1950, +25%; 1950-1963, -21%; 1963-1975, +8,85%. The current world reserves are 408 233 million tonnes, made up as follows: U.S.A., 20,0%; Chile, 19,1%; U.S.S.R. and Canada each 8,9%; Zambia and Peru each 6,7%; Zaire, 4,4%; Phillipines, 3,5%; Australia, 2,2% and other, 19,6%. Total South African reserves and demonstrated resources are only 1,30% of the world reserves but if the conditional resources are added this amounts to 3,74%. Hypothetical world resources (435 449 million tonnes of copper), speculative and unprospected resources (290 299 million tonnes) and presumed resources in subeconomic deposits (725 748 million tonnes) suggest that the inferred resources are probably large. At current utilization-depletion (i.e. production) of world reserves, the projected life is of the order of 68 years.

TRENDS, EVENTS, OUTLOOKS

Domestic

The estimated production of primary copper in 1975 (based on plant capacities) was 175 000 tonnes. Based on known expansion plans, a growth rate of some 7,9% per annum is estimated until 1985, giving a production of 314 000 tonnes of primary copper which, if new discoveries currently being developed can replace moribund supplies, will be maintained to the year 2000 (worth R430 million, 1976 rand). Current value of exports is about 62% of total sales and amounts to just over R91 million (1975).

World

Copper is supersensitive to world economic conditions and the fall in copper production has been felt since 1973. The year 1975 saw depressed conditions throughout the industry with a substantial build-up in stocks. From 1973-1974, stocks of copper grew by 38,4% and from 1974-1975 by 61,3% to a total of 1 262 million tonnes which is expected to effect trading for many years, although stocks held are only 32% of current annual world production. Copper is one of the metals in which world production has always exceeded apparent consumption and explains its sensitivity to economic situations. In 1938, production exceeded consumption by almost 27%, in 1950 by 8,4% and 3,4% in 1975. This situation may not last since from 1938-1975 apparent consumption has increased by 281% while production has only increased by 211%. Pressure has been exerted on copper by the possibility of substitution by aluminium and plastics and by the projection of a possible short supply in the future. On the other hand many factors, like its inherent favourable properties for utilization, operate in favour of the metal. Moreover, copper requires about a third of the energy required to produce an equivalent amount of aluminium which, in the present energy crisis situation, weighs heavily in favour of copper utilization. World growth appears to forecast a 5 to 5,5% growth increase for copper until the year 2000. Nevertheless the immediate outlook of copper is gloomy with the depressed metal price below or equal to production cost, and the large stocks on hand. If the world economy recovers, copper is sure to bounce back as stocks are depleted and prices rise. Copper prices and production fluctuations in the last decade have also adversely effected exploration activity and the stop-start tendency in exploration activity is wasteful of human energy so that long-term planning of copper exploration, regardless of price fluctuations, appears warranted.

DIAMONDS

General

Commodity Type

Diamonds are the octohedral or dodecahedral crystalline forms of carbon. Diamonds, which fulfil the gemstone quality of desirability and rarity, must also have the necessary transparency, brilliance, lustre and colour (white, blue-white, yellow, brown, green, red, blue and pale) and are largely used as jewellery after cutting and polishing. Industrial diamonds are those that lack the colour, structure or size to be classed as gem quality and are classed as die-stones (wire drawing), tool-stones (shaped tools), dresser-stones (for truing grinding wheels and tools), drilling stones (core bits, stone saws) and boart (for boart-impregnated grinding wheels, saws, bits and powders. Diamonds are classified into more than 100 groups (personal factor by trained personnel) according to quality, size, habit and colour. The standard carat is the "metric carat" of 200 milligrams (5 000 carats = 1 kilogram).

Utilization

Apart from the gemstone quality, the largest outlet for industrial diamonds is in the manufacture of abrasive grinding wheels, in grinding-wheel truing and dressing tools, in drilling bits, in lathe tools, in wire drawing dies and as hardness indentors. There is also utilization in diamond saws and diamond dust is used to polish metal parts and jewel bearings. The uses in U.S. industry are machinery, 32%; transportation, 20%; ceramic shaping, 19%; contract construction, 11%; drilling, 8%; other, 10%.

Geology, Exploration

Economically mineable diamonds occur in kimberlite pipes, dykes and sills of deep-seated origin, and in placer deposits. Over 90% of the world output of industrial diamonds originate from placer deposits. Geological evidence is that the diamond formed in the kimberlite although the numerous occurrences of barren pipes suggest that conditions were not always favourable for diamond

formation. The ratio of profitable to unprofitable pipes may vary from 1 in 3 (Kimberley) to 1 in 26 (Tanzania). Kimberlite placers range in age from Precambrian to Quaternary and may be raised beach deposits, alluvial deposits or old river gravels and terraces.

Magnetic and resistivity methods are used in locating diamond pipes but a particularly successful method is the so-called "grid loaming" in which tracer minerals are sought in heavy mineral separates from samples collected on a grid basis.

SOUTH AFRICA

Sources

In South Africa, about 150 kimberlite pipes are known to exist but only 25 have been extensively worked since many are not diamond-bearing. The pipes are generally of oval outline with near-vertical walls and it is almost always found that the yield decreases with depth once the superficial portion of the pipe has been penetrated. Groups of pipes are exploited at Kimberley, Postmasberg, Jagersfontein, Koffiefontein and Cullinan. Erosion of the pipes leads to the redistribution of the diamonds into inland (Lichtenburg, Ventersdorp) or coastal (Atlantic Coast) gravels or in ancient river gravels and terraces (Orange, Vaal and Harts rivers). The continental shelf off the west coast is a large potential source of diamonds. The first diamond discovery in South Africa was made in 1866. The chief producer of diamonds is the mines of the de Beers Group but other smaller units and the State Alluvial Diggings at Alexander Bay also account for a lesser proportion of the production. The chief marketing channel for Southern Africa's production is the Diamond Producers Association, one of the affiliates of the Central Selling Organisation which co-ordinates the bulk of the world's diamond sales.

Production

South African production from 1941-1975 was 129 167 665 carats as follows: 1941-1945, 1,7%; 1946-1950, 4,9%; 1951-1955, 9,5%; 1956-1960, 10,7%; 1961-1965, 16,7%; 1966-1970, 28,0% and 1971-1975, 28,5%. Production growth for the same period was 16,9% per annum as follows: 1941-1945, +74,25%; 1946-1950, +9,96%; 1951-1955, +9,61%; 1956-1960, +3,45%; 1961-1965, +12,53%; 1966-1970, +10,20% and 1971-1975, -1,89%. South African production contributed the following average of world production: 1941-1945, 4,57%; 1971-1975, 14,86%. In 1975 the South African production was 7 295 133 carats or 14,8% of world production.

Reserves, Resources

No internal estimates are available and only U.S.A. estimates of industrial quality diamonds are available. The reserves, according to that source, grew by 11% from 1963 to the 1975 estimate of 50 million carats or 7,35% of world reserves. Assuming 51,25% of production to be industrial stones as in 1974, the life of our diamond production is limited to 13 years at present production, unless new fields are discovered and exploited.

WORLD

U.S. Depletion Allowance

Domestic, 14%; foreign, 14%.

U.S. Prices

The import value of industrial diamonds has shown very little (+0,04%) annual growth but increased from 1961 as follows: 1961-1965, +0,47%; 1966-1970, -2,35% and 1971-1975, +1,99%. The 1975 price of \$4,00 per carat showed a 16,9% increase over the previous year and halted a falling price over the previous five years.

U.S. Import Sources

The U.S.A. imports (1958-1975) all her industrial diamonds from the following sources, the trends being shown in parenthesis: Ireland, 29,8% (16-48%); R.S.A., 18,6% (32-13%); U.K., 18,2% (41-11%); Belgium-Luxembourg, 8,1% (10-6-11%); Congo, 6,7% (10,0%) and other, 18,6% (variable).

Production

Production of industrial diamonds grew by 1,88% per annum from 1961-1975 as follows:

1961-1965, +1,85%; 1966-1970, +1,51%; 1971-1975, +2,29%, to reach a total of 32 million carats in 1975. This was 64,8% of the gem plus industrial production during that year which totalled 49,38 million carats. The following countries shared in the industrial diamond production during 1974: Zaire, 37,8%; U.S.S.R., 25,1%; R.S.A., 13,0%; other Market Economy Countries, 9,5%; and Botswana and Ghana each 7,3%. The following countries shared in total production, gem and industrial, during 1974: Zaire, 33,7%; U.S.S.R., 23,8%; R.S.A., 15,9%; Botswana, 5,3%; Ghana, 4,8%; Angola, 4,4%; Sierra Leone, 3,4%; S.W.A., 3,2% and other 5,5%. In 1974, 51,25% of South African production was industrial diamonds.

TRENDS, EVENTS, OUTLOOKS

Statistics about diamonds seem even less reliable than those about many other minerals and very conflicting opinions occur in the literature.

Domestic

Of African producers, only South Africa has a local diamond cutting industry. It flourishes under government protection which ensures that rough diamonds are sold to the trade at ruling London prices less 10% and also that the stones are above average in size. About 30% of the countries gem-stone production in 1969 went to the South African diamond cutting industry. It would seem reasonable to expect that the local diamond industry will grow at least as rapidly as the economy of the country. The 1975 value of diamond sales was R174 221 million (mined stones, 53,3%, alluvial, 46,7%).

World

U.S. demand for industrial diamonds is expected to increase at an annual rate of about 4% until 1980. Production of synthetic stones in that country depends heavily on the importation of pyrophyllite (wonderstone) from South Africa. Synthetic production of larger stones is not commercial, but it is nevertheless estimated that 50% of larger stones classified as industrial, can become gem-stones by lazar beam treatment. Carbon boron nitride, synthesized by methods similar to those used in making industrial diamonds, has been used successfully as a substitute for industrial diamond in ever increasing applications during 1975. There appears to be no real substitute for gem diamonds and demand will continue to grow.

Much uncertainty has surrounded diamond production of late. The civil war in Angola considerably affected production from that source and the uncertainties which surround the future of South West Africa must also cause some concern in diamond circles. Diamonds have been affected in the same way as other commodities during the current recession, but appears to have emerged in a strong position and an escalation of 3% in the price of diamonds was expected during 1976.

FLUORSPAR

General

Commodity Type

Although other minerals contain the versatile element fluorine (cryolite, fluorapatite, topaz), only the mineral fluorspar will be considered here. Fluorspar or fluorite is marketed in three grades: acid, ceramic and metallurgical. Acid-grade fluorspar contains a minimum of 97% CaF₂ and a maximum of 1,5% silica, with limits on limestone, sulphide sulphur or total sulphur, iron, lead, zinc and phosphorous. Ceramic-grade fluorspar varies according to consumer demand but generally contains 85-96% of CaF₂ with limits on silica, limestone, ferric oxide, sulphide sulphur, lead and zinc. Metallurgical grade fluorspar (metspar) is commonly listed in market quotations as 60,70% and 72,5% effective CaF₂ units (i.e. a measure obtained by multiplying the silica content of the ore by 2,5 and subtracting this figure from CaF₂ content). Consumers desire lump metspar with maximum limits of 0,3% sulphide sulphur and between 0,25% and 0,5% lead.

Utilization

Fluorspar is used mainly as an open-hearth flux in the steel industry, as an iron-foundry flux and as a nonferrous metals flux. It also looms large as an additive in electrometallurgy. None of the possible substitutes (calcium chloride, bauxite or colemanite - hydrated calcium borate) appear usable on a large scale. Fluorine gas, derived from fluorspar, is used to reduce alumina to aluminium metal, for the production of hydrofluoric acid (fluorocarbon) and fluorosilicates. Fluorocarbons are used in many ways but mainly as refrigerants, aerosol propellants, solvents and in

specialised plastics. Demand is escalating as new uses are found for these unique compounds. Fluorine is also used in the ceramic, glass, welding-rod and enamel industries. The 1975 U.S.A. use of fluorpar was: the steel industry, 47%; the chemical industry, 30%; the magnesium-aluminium industry, 20% and other combined, 30%. An alternate survey suggested a 1975 world-wide consumption as follows: steelmaking, 53%; fluorocarbons, 25,7%; aluminium, 16,0%; stainless steel pickling, 3,2%; petroleum alkylation, 1,8% and uranium enrichment, 1,1%.

Geology, Exploration

Fluorine deposits are classified into the following four groups based on rock association although there is considerable overlapping and intergrading of the various classes: (1) with igneous rocks as disseminated, pegmatite and carbonatite deposits and deposits in contact aureoles; (2) with volcaniclastic and lacustrine sedimentary rocks and those in evaporite, marine carbonate and phosphorite rocks; (3) with regionally metamorphosed rocks and (4) hydrothermal deposits in veins, mantos, pipes and stockworks and zones of alteration.

The important geological parameters for fluorspar search are regional tensional faults or other deep-seated structures, alkaline and siliceous igneous rocks, carbonatites and hydrothermal activity. Fluorine is apparently very mobile in geological settings characterized by these parameters and, in addition to forming deposits directly related to these features, it may also have moved to other favourable environments in time and space to form deposits there. Large deposits of fluorapatite may be located in the upper portion of the mafic sequence of the Bushveld Complex and in younger marine sediments.

Fluorspar deposits are mostly identified on outcrop and although buried deposits should have a geochemical response; geochemistry has not been widely used but may be important in future. On the other hand, fluorine haloes are common in many mineralised and altered areas and may be meaningless for actually locating fluorspar deposits and their use as a guide will require considerable geological knowledge of the prospect area. Pathfinder lead, zinc and mercury may be useful fluorspar indications. Heavy mineral techniques may prove more rewarding as fluorspar is resistant to long-distance transport but the method is not well developed. Geophysical methods are useful in defining faults or fractures and alteration zones associated with the mineralisation but direct location of mineable bodies appears impractical. Much research into the geology and geochemical cycles of fluorine is needed, as well as research into exploration methods.

SOUTH AFRICA

Sources

Most fluorspar occurs as hydrothermal or metasomatic replacement deposits associated with igneous, sedimentary or metamorphic rocks. Most fluorspar deposits are found either in the Bushveld acid rocks or in the dolomites of the Transvaal Supergroup in the western Transvaal (Zeerust). They occur as lenses or irregular lens-shaped bodies or as branching to somewhat irregular veins. In the Bushveld acid rocks they are often associated with specularite. In the dolomites they are metasomatic replacements associated with lead and zinc ores. Lesser deposits are known from the Richtersveld in Namaqualand and from the Kakamas and Kenhardt areas. Deposits are known to occur in the Hlabisa area of Zululand.

Production

The total output of fluorspar from 1941-1974 was 2 453 286 metric tonnes produced as follows: 1941-1945, 0,8%; 1946-1950, 1,0%; 1951-1955, 3,5%; 1956-1960, 11,2%; 1961-1965, 15,0%; 1966-1970, 24,8%; and 1971-1975, 43,7%. For the last four years, from 1975 the average of production was 83,5% acid grade, 12,0% metallurgical grade and 4,5% ceramic grade. The growth in production was 14,80% per annum from 1941-1975 as follows: 1941-1945, -9,98%; 1946-1950, +16,42%; 1951-1955, +37,67%; 1956-1960, +30,36%; 1961-1965, -4,59%; 1966-1970, +21,66% and 1971-1975, +12,08%. Actual production during 1975 was 202 583 tonnes which is 4,56% of world production.

Reserves, Resources

According to figures released in 1974 (Gössling, 1974), the proven reserves were 118 million tonnes as follows: 60 million tonnes in the western Transvaal dolomites; 40 million tonnes in the Bushveld acid rocks and 18 million tonnes of the Rust der Winter area. Revision by the same author in 1976 suggested 116 million tonnes with a CaF_2 content of 25%. The bulk of the Bushveld ore is contained in the Buffels fluorspar mine west of Naboomspruit. The deposit at Kromdraai 209 JR south of Rust der Winter contains 18 million tonnes but the total extent of this mineralisation remains to be delineated. Martini (1976) estimated the fluorspar deposits of the Marico district, with an average grade of 15% CaF_2 to be between 100 to 150 million tonnes of ore (15-22 million tonnes fluorspar). Von Gruenewaldt (1976) suggested that the total resources of these deposits may be conservatively estimated at between 34 to 42 million tonnes of fluorite, with a further 10 million tonnes of fluorite

in other deposits of the Bushveld (Wydhoek, Kruidfontein, Walmansthal). Assuming indicated reserves of only 30 million tonnes of contained fluorite, this constitutes some 27,6% of world reserves. At present production, the reserves could last for about 148 years. The possible resources are probably large.

WORLD

U.S.A. Depletion Allowance

Domestic, 22%; foreign, 14%.

U.S. Prices

From 1961-1965, fluorspar showed no price rise in the U.S.A. (mine value) but from 1966-1970 the price rose by 8,96% giving an average annual price rise of 4,48% from 1961-1970. From 1972-1975 the U.S.A. mine price for acid grade fluorspar increased by 4,98% per annum and that of metspar by 5,81% per annum. If average U.S.A. mine prices for acid grade fluorspar and metspar for the years 1961-1963 are compared with those for 1971-1973, they show increases of 70,51% and 74,27% respectively for the ten year period, or an apparent increase of 7,0% and 7,4% per annum.

U.S. Import Sources

These are as follows, with the figures in brackets indicating the trend from 1958-1974: Mexico, 74,1% (61-78%); Spain, 13,7% (16-13%); Italy, 8,6% (18-5%) and others, 3,6%.

Production

The average world production growth from 1961-1975 was 5,96% as follows: 1962-1965, +8,67%; 1966-1970, +7,77%; 1971-1975, +1,45%. The consumption of all grades of fluorspar in the Western world decreased by 4,7% in 1974-1975 and production by 4,8%. In 1974, a total of 39,8% of world production was metallurgical-grade fluorspar, and 60,2% was acid-grade fluorspar.

The sources of fluorspar during 1974 were as follows: Mexico, 24,9%; Italy, 7,4%; Thailand, 7,3%; Spain, 6,9%; France, 6,6%; Republic of China, 5,7%; South Africa, 4,3%; U.S.A. 3,7%; U.K., 3,5%; Canada, 3,4% and others, 26,3%, the countries listed all producing more than 100 000 tonnes of the total production of 4 732 million tonnes. Production figures for the U.S.S.R. were not available but in 1973 it produced 8,9% of world production.

Reserves, Resources

The world resources of fluorspar ore escalated from 36,287 million tonnes in 1950 to 172,365 million tonnes in 1973 to 327 million tonnes in 1975. World reserves in 1975 are stated to be at least 195 million tonnes of contained CaF_2 as follows: South Africa, 27,6%; U.S.A., 10%; France, 7,3%; Mexico, 7,2%; Italy, 5,7%; U.S.S.R., 4,7%; Kenya, 4,3%; China, 4,0%; Spain, 3,8%; Thailand, 3,7%; Argentine, 3,4%; U.K., 3,3%; Canada, 2,4% and others, 12,6%. These reserves shows an apparent life of 22 years.

During 1974, 12,6% of the total acid-grade fluorspar production was agglomerated to supplement the declining production of metspar which is ascribed to the rapid depletion of economically-proven reserves of that commodity in the main producing countries. This proves that the main reserves are mostly of acid-grade fluorspar. According to present production levels, the proven and economically extractable reserves of France, Italy, West Germany and Thailand and possibly the U.K. are expected to be depleted in about 10 years time. It therefore appears reasonable to predict that South Africa will become the world's main supplier of fluorspar from 1985 onwards.

Identified resources of fluorine of the world may be as high as 762 million tonnes, of which about 6% of fluorspar equivalent may be by-product fluorine in phosphate rock. With present recovery methods, only about 30% of the fluorine in the identified resources is recoverable although total world resources of fluorine may be ten times larger than estimated.

TRENDS, EVENTS, OUTLOOKS

Domestic

It is estimated that the growth rate of fluorspar which has been high over the last decade (average 16,87% per annum) should slow down to a rate of 7,3% per annum. This suggests that production

in the year 2000 may be as high as 1,3 million tonnes of fluorspar. A substantial portion of this will probably be as pellets as is already being done in South Africa to overcome the serious shortage of gravel spar for metallurgical purposes. South African sales of fluorspar during 1975 were as follows: acid grade, local 5 397 tonnes (R239 268), exports, 126 061 tonnes (R6 706 122); ceramic grade, local 9 237 tonnes (R421 462), exports 39 tonnes (R2 192); metallurgical grade, local 14 516 (R423 538), exports 454 tonnes (R20 865). On balance of value, exports are about 96% of total sales.

World

In keeping with the world-wide recession, fluorspar production and prices have been somewhat uncertain but as the effects of the recession could recede, demand for fluorspar may be expected to recover in the years ahead. The steel industry is confidently expected to re-instate and expand its substantial demand, provided that the world steel production maintains an accumulated annual growth of 4% per annum to 1980. None of the extensively-tested fluorspar substitutes has come up to expectation in the steel industry. The alumina industry has been affected by the production of waste fluosilicic acid from the fertiliser industry but the costs involved are not comparable with the conventional fluorspar route. Consequently the demand for fluorspar by that industry is expected to continue although at a reduced growth level. The situation in respect of the chemical industry is more difficult to assess especially in respect of which proportion of the reduction is attributable to the industrial recession and which proportion is related to the widespread publicity and consequent consumer reaction to the controversy surrounding the ozone-layer depletion by chlorofluorocarbons. Even if proved scientifically unfounded, public sentiment and its effect on the aerosol industry will probably remain. Nevertheless an annual growth of 9,5% to the year 1980 seems possible with a consequent 38% increase in the demand for acid-grade fluorspar to that date. Other industries are projected to increase demand by about 44% to 1980. The future for the commodity appears to be bright at an overall growth rate of about 5% per annum to 1980. Nevertheless it must be stressed that the pattern of fluorspar consumption is changing, with a projected decline in demand by the aluminium industry possibly being offset by an increased demand in the chemical industry. Steel-production requirements remain dominant with acid-grade agglomerates increasingly replacing falling metspar production.

GOLD

General

Commodity Type

Gold is a high-density, soft and malleable metal that is easily shaped. Because of its workability, beauty, durability and common occurrence as the native metal, it was one of the first metals worked by man. It has been the principal international monetary medium for many years. Fineness defines the proportion of pure gold in bullion or coin expressed in parts per thousand; fine gold is 100% pure or 1 000/1 000 fine. Gold's physical properties make it prized for jewellery and adornment. The term "karat" in jewellery means 24th part so that pure gold is 24kt.; 18kt. contains 18/24 or 75% gold with a tolerance of 1/2 karat (or carat) being permissible. Coloured golds are basically ternary alloys of gold, silver and copper, with white gold being generally composed of gold, copper, zinc and nickel. Yellow gold is an alloy of gold and copper with some silver or zinc and green gold is chiefly gold and silver, containing some copper and zinc.

Utilization

Most of the world's gold production is absorbed by governments and central banks to provide stability for paper currencies and to settle international trade balances but in recent years large quantities of gold are privately held. The official monetary reserves in 1972 were estimated to be about 1 300 million ounces of gold out of an estimated 3 000 million ounces which are likely to have been produced throughout mining history. The chief nonmonetary uses are in jewellery and decorative arts (U.S. 1968, 59% of demand) including watch cases, utensils, gold leaf and decorative finishes. Gold in various alloys with the platinoid metals, is used in dentistry, for spinnerets for making synthetic fibre, thermocouples, electrical contacts and scientific laboratory equipment. Electric components accounted for 27% of U.S. demand in 1968. Appreciable quantities of gold are consumed in the field of optics, atomic energy, heat control and measurement, medical therapy, chemical manufacture and brazing. Space technology and defence are major users of gold (semi-conductors, printed circuits, connectors, computer micro-components). Non-monetary use of gold in the rest of the world is estimated at 3 or 4 times that in the U.S.A. The principal secondary non-monetary uses in the U.S. in 1975 were: jewellery and art, 47% (steady decline from 66% in 1964); dental, 16% (escalating from 7% in 1964); industrial, 33% (up from 26% in 1964) and investment, 4%.

Geology, Exploration

Gold occurs in many and varied geological environments such as: (1) Gold-quartz lodes - hydrothermal veins replacing wall rock or fracture fillings; (2) Epithermal or "Bonanza" deposits - fracture fillings of gold tellurides and silver associated with quartz, carbonates, barite and fluorite; (3) Ancient and recent placers mostly in conglomerates; (4) Marine placers; (5) Disseminated gold (Carlin) deposits in silty and carbonaceous dolomites and (6) By-product gold recovered from other ores.

The gold pan has been an effective method of gold prospecting through time, taking into account the high density, resistance to tarnish, distinctive colour etc. of the metal. Gold placer deposits appear to be confined to the mid-Precambrian age (2 700-1 600 million years). Although geochemical methods of locating gold are limited, advances in atomic absorption spectrophotometry could make this a viable method. Gold has thus been prospected for by somewhat indirect geological and geophysical methods to date, although satellite imagery probably presents an exciting new tool in this regard. Other fields which need to be explored are the applicability of mercury sniffer techniques and the possibility of exploitable gold within mafic rocks and in porphyry copper deposits and their wallrocks.

SOUTH AFRICA

Sources

The main source of gold in South Africa is the fluviatile conglomerate reefs, quartzites, shales and algal mats of the Proterozoic Witwatersrand Supergroup. The Witwatersrand Supergroup mines occur in three main areas; the Witwatersrand proper which can be subdivided into the Leslie-Kinross area of the far East Rand, the East Rand, the Central Rand, the West Rand and the West Wits line; the Klerksdorp field and the Free State field. Gold has also been extracted from the Transvaal Supergroup (within conglomerates, shales, silty dolomites and dolomites of the upper transition of the dolomitic Chuniespoort Group in the moribund Pilgrims Rest field); from the Pongola Supergroup (in conglomerates and shales) or from the Archaean greenstone belts (strata-bound within the lower and upper divisions of the essentially volcanic Onverwacht Group, the so-called Middle Marker, and also at the contact of the upper Onverwacht Group and the overlying sedimentary Fig Tree Group). It has been calculated that the older Pongola and Archaean ores contributed only 1,77% of production up to 1971, with 98,23% originating from the later Witwatersrand (96,75%) and Transvaal (1,48%) sedimentary basins. Gold production from other sources, mainly as a by-product of platinoid mining of the Merensky Reef is probably a less important source.

Production

From 1941-1975, South Africa produced 21 874 514 kg. of gold as follows: 1941-1945, 9,4%; 1946-1950, 8,2%; 1951-1955, 9,0%; 1956-1960, 13,0%; 1961-1965, 19,1%; 1966-1970, 22,1% and 1971-1975, 19,2%. In 1975, the gold production was 713 477 kg. Annual growth in production has averaged only 1,66% from 1941-1975 as follows: 1941-1945, -2,66%; 1946-1950, -0,88%; 1951-1955, +4,71%; 1956-1960, +8,41%; 1961-1965, +7,48%; 1966-1970, +1,04% and 1971-1975, -6,50%. It would thus appear as if South Africa has already passed the production peak, the highest production of over one million kg. of gold having been attained in 1970.

Reserves

Estimates of present gold reserves vary. One source suggests 15 million kilograms fine as mineable reserves, another 18,66 million kilograms as total reserves. The latter figure suggests that South Africa contains about 60% of the world reserve. At the 1975 production figure, the reserves should last for between 21 and 26 years. The potential for locating new gold resources is probably favourable.

WORLD

U.S. Depletion Allowance

Foreign and domestic, 15%.

Prices

From 1934-1972, the United States maintained full convertibility of the dollar to gold at a fixed price of \$35 per ounce. Post-war balance of payments deficits and rising industrial use of gold, caused a steady drain of the U.S. monetary reserves. In March 1968, the seven major monetary nations (U.S.A., Great Britain, Belgium, Italy, Netherlands, Switzerland and West Germany) decided to discontinue

open-market dealing in gold but to continue inter-governmental transactions at the fixed \$35 per ounce. As a result of this agreement, the U.S. treasury stopped selling gold from its stockpile for industrial use, but the balance of payments continued to drain the official reserves. Thus on 16th August 1971 the U.S. Government suspended convertibility. As a result, the Group of Ten Nations (as above without Switzerland but including Canada, France, Japan and Sweden) agreed to raise the price of gold to \$38 per ounce on 18.12.71 and this agreement was signed by the U.S. president on 3rd April 1972. After establishing a free market for gold in 1968, the price fluctuated between \$35 and \$45 per ounce until early 1972 when the price rose sharply. During the latter years the U.S. gold reserves fell to around \$10 billion whereas their liabilities to foreign central banks and monetary authorities was four times that amount, creating a vast speculative position against the dollar. This had the influence of an unprecedented wide fluctuation in monetary parities causing devaluation adjustments as a logical companionship of continued accelerating inflation. This stimulated the demand for free-market gold, thereby causing a widening margin between the two-tier varying free-market price and the static official price, frequently motivating calls for drastic measures to ensure international monetary reconstruction. The energy crisis and the near anarchy it produced in international monetary systems, has augmented these demands. Yet the problem lies in the disparity between those who are intent on demonetising gold and those who have striven to maintain some official rate for the metal. The present position (see further below) is that the official gold price has been abolished and currency parities are no longer expressed in terms of the metal. From 1965-1970 the price fluctuation was somewhat variable but showed an overall rise of +1,12% per annum but for the following five years the rise was somewhat dramatic at an average +37,43% per annum although the price showed stabilization during 1975 (+1,56%), averaging \$162,25 per ounce.

U.S. Import Sources

U.S. import sources of gold for the years 1958-1975 were as follows, the figures in brackets representing temporal changes in the contribution of various sources: Canada, 38% (67-0-51%); Columbia, 10% (0-31-0%); Phillipines, 9% (5-24-0%); Switzerland, 8% (12-27-24%); U.K., 3% (9-3%); Venezuela, 2% (0-14-0%); Nicaragua, 2% (3-6-0%); Burma, 2% (0-9%); Uruguay, 1% (0-16-0%); U.S.S.R., 0,5% (one year 6%); Japan, 0,5% (one year 5%) and other 24%. It is almost surprising that South Africa does not constitute a direct recorded source of gold import to the U.S. economy.

Production

World production of gold has shown an overall annual drop of 1,3% during 1961-1975 as follows: 1961-1965, +0,17%; 1966-1970, -0,13%; and 1971-1975, -3,93%. During 1975, the following free world countries contributed to production: South Africa, 75,3%; Canada, 5,4%; U.S.A., 3,4%; Rhodesia, 2,1%; Papua/New Guinea, 2,0%; Ghana, 1,9%; Phillipines, 1,7%; Australia, 1,5%; Columbia, 1,1% and others, 5,6%. If the communist countries are taken into account (1974 figures) the contribution is as follows: South Africa, 61,2%; Canada, 4,3%; U.S.A., 2,8% and others 31,7%. During 1974, world mine production was 1,237 million kilograms of gold while the free world produced 0,940 million kilograms of gold during 1975.

World Resources

World resources of gold rose from 31,103 million kilograms in 1971 to 41,990 million kilograms in 1975, a rise of 35%. The 1975 reserve estimate is made up as follows: South Africa, 59,2%; Central Economy Countries, 15,6%; other Market Economy Countries, 10,4%; U.S.A., 8,9%; Canada, 3,7% and Australia, 2,2%. At the 1974 world production rate, the reserves could last for about 34 years although no estimates of world resources are available.

TRENDS, EVENTS, OUTLOOKS

Domestic, World

The worldwide pattern of gold consumption has recently changed. The higher price and the economic recession have enforced substitution so that gold consumption for non-monetary uses fell 31% in the U.S.A. and 28% in Europe which was offset by a strong stimulation of investment demand as a hedge against inflation, weak security markets and continued currency unrest. These patterns make predictions for the future of gold extremely difficult but optimistic opinion suggests that both investment and industrial demands will increase in the long term.

With gross uncertainty in a world in upheaval, coupled equally to permissive differential and high inflationary and energy-crisis instabilities, gold remains a hedge and refuge against a capricious monetary system. In spite of U.S. hostility against gold and its move to demonetise the metal, it remains true that "the modern mind dislikes gold because it blurts out unpleasant truths" and many moves and measures to play down the role of the metal appear to be unsuccessful; in fact the role of the metal in the international monetary system has increased. Nevertheless, floating currencies are currently tolerated as the accepted legalised norm and this places at least some uncertainty on the monetary future of gold.

The decision of the IMF has been to sell gold (8 auctions per year to recent biweekly auctions for four years) at free market price, the profit to be transferred to a trust fund for distribution to less developed countries. This is tantamount to an abuse of international monetary reserves for the cause of economic assistance. This has placed uncertainty on a stable gold price but it would appear that it cannot last with the SDR and IMF reserves only constituting some 7% of total gold and currency reserves. The latest price rises, unless they are due to speculative buying, appear to recognise this fact. Thus the dismissal of gold from the international monetary scene is more apparent than real as it continues to be the only item of international liquidity and reserves. As such, there is a wide-spread official vested interest in maintaining a relatively high price for gold.

IRON

General

Commodity Type

Iron is the principal metal employed in modern industrial civilisation. Its abundance and properties make its fabrication into a myriad of useful forms possible and, in combination with other elements, to produce many useful compounds. Nations are ranked in industrial development partly on a basis of total production and per capita consumption of steel.

Nearly 300 minerals contain iron as an essential component but only six of them are classed as ore minerals, notably the oxides magnetite, hematite and goethite (limonite). The other major ore minerals are the iron carbonate, siderite, and the sulphides pyrite and pyrrhotite, but are only mined locally.

The five principal grades of iron are: (1) bessemer (less than 0,045% P); (2) low phosphorous, non-bessemer (0,045 to 0,18% P); (3) high-phosphorous (over 0,18% P); (4) manganiferous (over 2% Mn); and (5) siliceous (over 18% silica).

Utilization

Iron ore is used almost exclusively in the iron and steel industry and in 1975, 98,3% of U.S. production was used in blast furnaces, 1,2% in steel furnaces and 0,5% in the manufacture of cement, heavy-media materials and other products.

Other uses of iron include paint pigments, cement, basic refractories, a fluxing agent in nonferrous smelting and as a constituent of some catalytic agents. Lump magnetite is often used in heavy-aggregate concrete, as a shielding material in nuclear powerplants, for the medium in jig beds and sink float plants and occasionally as ships ballast.

Geology, Exploration

Commercial deposits are Precambrian bedded sedimentary deposits (ironstones and banded iron-formations); deposits related to igneous activity such as magmatic segregations or pyrometasomatic deposits; hydrothermal replacement or enrichment deposits and near-surface enrichment or placer sedimentary deposits such as laterites, "black-band" siderites, bog iron ores or clastic accumulations.

Due to the abundance of iron ores and their low intrinsic value, exploration methods differ significantly from those of other major commodities. Being magnetic and usually having a surface expression, they are comparatively easy to discover. Relatively cheap and rapid airborne magnetic surveys followed by surface mapping and ground-based magnetic surveys are almost exclusively utilized in iron-ore prospecting. Economic factors such as location, infrastructure, large size, suitability of low-cost mining and beneficiation and low contents of deleterious impurities are critical in locating viable ore deposits. The proving of an economic deposit by drill-sampling can be costly and environmental consideration could constitute a limiting factor. The challenge to iron-ore mining lies in the viable utilization of low-grade carbonate, silicate and titaniferous ores.

SOUTH AFRICA

Sources

The most important iron ores of South Africa are a sedimentary type within the Transvaal Supergroup. In the Postmasburg area of the Cape Province, ferruginised Gamagara shale and conglomerates constitute the main ore types with banded ironstones and the Blinkklip breccia being more subordinate.

In the Thabazimbi area of the Transvaal, extensive deposits of hematite occur within banded iron-formation and ferruginous chert at the top of the dolomitic Chuniespoort Group, while siliceous iron ores of the Daspoort formation of the Pretoria Group are mined near Pretoria. Many other occurrences of ore or potential ore exist within these sequences. The main reserves of relatively clean magnetites are from the Palabora carbonatite. Large tonnages of vanadiferous and titaniferous ores (maghemites) are contained in the 21 magnetite seams in the upper portion of the mafic Bushveld Complex. Numerous occurrences of iron ore of many types are known throughout South Africa.

Production

From 1941-1975, South Africa produced 150 439 480 tonnes of iron ore as follows: 1941-1945, 2,4%; 1946-1950, 4,4%; 1951-1955, 6,0%; 1956-1960, 8,2%; 1961-1965, 15,5%; 1966-1970, 25,9% and 1971-1975, 37,6%. The annual production growth increased by 9,44% per annum for the same period as follows: 1941-1945, +6,99%; 1946-1950, +6,93%; 1951-1955, +11,39%; 1956-1960, +9,45%; 1961-1965, +14,00%; 1966-1970, +5,50% and 1971-1975, +11,84%. The 1975 production of iron ore was 12 297 776 tonnes of approximately 75% hematite and 25% magnetite.

Reserves

Ore reserve and resources estimates through the years are as follows:

Source	Total Millions Metric Tons	Qualification
Wagner, 1928	1 819 813 (resources)	108,86 million metric tonnes as +60% Fe "probable" available reserves. Total reserves 5 443 million tonnes
Mineral Resources 1959	1 822 988 (resources)	High grade (+55% Fe) = 1 179,34 million tonnes. Low grade (40-55% Fe) = 5443,11 million tonnes. Bushveld = 1995,80 million tonnes. Potential ore (25-40% Fe) = 1 814 370 million tonnes
Various (as below) Zietsman, 1973	2 014 000 (resources)	High grade (+60% Fe) = 4 027 million tonnes proved reserve, + 1 000 million tonnes possible
Schutte, 1975, 1976		Magnetite quartzite (30-50% Fe) 90 million tonnes as demonstrated resources. Titanium-vanadium ores, (50-60% Fe, 12-20% TiO ₂) 2 300 million tonnes as demonstrated resources, 4 100 million tonnes as inferred resources
Wagner, 1928		Banded ironstone (25-40% Fe) 2 000 000 million tonnes as identified resources
Alberts, 1965		Palabora magnetite (60% Fe, 0,5-5% TiO ₂) 100 million tonnes as demonstrated resources
Greathead, 1964		Chrome-rich ore (20% Fe) 2 000 million tonnes as identified resources
Van Rensburg, 1966		Manganese-rich ore (less than 35% Mn, 65% Fe + Mn). Large, not quantified.

Thus the iron ore resources have only increased by 10,67% since 1928, and 2 billion (British) tonnes is probably a good figure to accept although it may be as high as 10 billion tonnes. At the rate of 1975 production the overall resources would last almost indefinitely, although the reserves and possible reserves of +50% Fe would probably only last for some 7½ years on present indication. It should be noted that the total R.S.A. resources include subeconomic, hypothetical and speculative resources and that demonstrated resources (5 127 million tonnes) are only about 0,25% of total resources.

WORLD

U.S. Depletion Allowance

Domestic and foreign, 15%.

U.S. Prices

The price for natural ores (51,5% Fe) at Great Lakes ports rose by 3,53% per annum from 1960-1976 as follows: 1960-1965, -1,56%; 1965-1970, +0,46% and 1971-1975, +11,69%. The 1975 price was \$18,62 per long ton.

U.S. Import Sources

The import sources were as follows (1959-1974), the figures in parenthesis indicating trends: Canada, 49,8% (34-55-46%); Venezuela, 30,6% (41-26-31%); Chile, 4,6% (11-4-0%); Liberia, 4,3% (0-7-6%); Brazil, 1,2% (0-8%); Peru, 1,1% (6,0%) and other, 8,4%.

Production

World annual production growth has been 4,27% for the period 1961-1975 as follows: 1961-1965, +5,15%; 1966-1970, +4,52% and 1971-1975, +3,13%. World production in 1975 was 875 million tonnes (provisional) as follows: U.S.S.R., 26,0%; Australia, 11,4%; U.S.A., 9,2%; Brazil, 8,1%; China, 6,8%; Canada, 5,7%; France, 5,4%; India, 4,1%; Sweden, 3,6%; Venezuela, 2,7%; Liberia, 2,5%; South Africa, 1,4%; Mauritania, 1,2% and others, (33 countries) 11,9%.

Reserves, Resources

In 1963, world resources were estimated to be 123 958 million tonnes; 198 129 million tonnes in 1965; 203 209 million tonnes in 1967; and reserves of 252 000 million tonnes in 1970 with an additional +779 000 million tonnes as identified resources. These represent increases of 59,8% (1963-1965); 2,6% (1965-1967) and 24,0% (1967-1970). By 1975, the reserves were estimated at 263 156 million tonnes (+4,4%, 1970-1975) containing 101 605 million tonnes of 38,6% recoverable iron. In the same year identified resources were 772 195 million tonnes. The average indicated growth of reserves and resources appears to be about 6,5% per annum. Reserves of recoverable iron in 1975 in different countries of the world, were as follows: U.S.S.R., 31,0%; Brazil, 16,0%; Canada, 12,0%; Australia, 10,0%; other Market Economy Countries, 10,0%; India, 6,2%; U.S.A., 4,0%; China, 3,0%; France, 2,7%; Venezuela, 2,3%; Sweden, 2,2%; and other, 0,6%. With the 1975 production figures as a base, present world reserves should last for some 300 years.

TRENDS, EVENTS, OUTLOOKS

Domestic

The main producers of iron ore are the South African Iron and Steel Industrial Corporation Limited (ISCOR, semi-government), Associated Manganese Mines of S.A. Limited and Consolidated African Mines Limited. Based on world's standards, South African production is small (1,3% in 1974; 1,4% in 1975), but production growth is expected to escalate at an average annual rate of 9,1%. Based on announced plans of existing steel producers, the domestic hematite consumption in the year 2000 should amount to 58 million tonnes per annum. On the same basis, exports should be 30 million tonnes per annum, taking the Saldanha Bay harbour into account. In terms of 1976 constant rand, export earnings will be worth R400 million and total production R750 million by the year 2000.

A recent trend is to produce sponge iron and this industry is expected to expand. Present production is about 100 000 tonnes but should approach 1,5 million tonnes by 1985 and 3,0 million tonnes by the year 2000 (worth R300 million, 1976 rand). Production of crude steel in 1975 was 6,3 million tonnes valued at about R750 million. Iscor accounted for 73% of this tonnage. Steel production is expected to escalate at between 5% and 6% per annum, on which basis output in the year 2000 will be between 16,8 million tonnes (value R2 000 million, 1976 rand) and 33,8 million tonnes. These figures are quoted from Shearer (1976) and Maxwell (1976).

World

Due to the economic slump, world steel producers have high ore stocks so that exports are not expected to recover until late 1976 depending on the economic climate. If the recession recedes, there could be a possible supply shortage of iron ore by 1980. Aspects for concern are increased rail charges and the escalating costs of capital projects which have been delayed due to lack of available

funds. U.S. demand is expected to increase at an annual rate of 1,5%. If iron ore production in the world increases by 5% per annum, production will be 3 170 million tonnes in the year 2000 and South Africa will have increased her share to 2,4%.

LEAD

General

Commodity Type

The use of lead predates those of iron and, with copper and silver, may be the earliest metal used by man and thus has a long record of utilization through time. The dominant lead mineral is galena (PbS) which may contain significant amounts of silver. Many galena deposits are altered to cerussite (PbCO₃), anglesite (PbSO₄), pyromorphite (complex lead chloride and phosphate) or other minerals but they are insignificant to lead production. A great number of lead minerals are complexed with silver, copper and antimony and a large number of sulphide minerals (pyrite, chalcopyrite, tetrahedrite, tennantite, argentite, etc.) are commonly found with galena. Lead is a soft, heavy, malleable but only slightly ductile metal. It has an S.G. of 11,35, a melting point of about 327°C and boils at about 1 700°C. It is a radioactive decay residue. Refined lead is marketed in seven grades: corroding, chemical, acid, copper lead, common desilverised and soft undesilverised, each with a unique specification. Large quantities of lead are marketed in various lead- or copper-based alloys.

Utilization

Lead is the fifth-ranking metal of trade and consumption after iron, aluminium, copper and zinc. The consumption is dominated by storage batteries, leaded motor fuel and by the construction industry. It is used extensively in metal products (ammunition, bearings, brass and bronze, cable coverings; in castings and caulking; in foils, pipes and tubes; in sheet lead, solder and terne and type metal), in pigments (white and red lead litharge etc.), in chemical products (anti-knock additives, batteries) and miscellaneous uses (annealing, galvanizing, plating and ballasting). In 1975, the U.S. secondary use of lead was: batteries, 53%; fuel additives, 16%; electrical, 7%; ammunition, 7%; paints, 6%; construction, 4% and other, 7%.

Geology, Exploration

Deposits of lead occur as syngenetic stratabound deposits in sediments, as epigenetic stratabound or stratiform deposits, as volcano-sedimentary deposits and as replacement deposits including mantos, veins and contact pyrometasomatic deposits in granite-pluton aureoles.

Most lead deposits are found through direct exploration of underdeveloped areas, in which conditions are similar to known fields, although new types of deposits have been found. Modern geological techniques are planned, using models of known mineralisation to explore remote regions. Geochemical methods of search are used in conjunction with geological mapping especially in areas which are geologically favourable. Geophysical methods rely on contrasting physical properties of the ore (density, magnetism, conductivity, induced polarisation, radioactivity or seismic response) which contrast with their enclosing country rock. Depending on such characteristics, airborne methods (magnetic, electromagnetic) may be used.

SOUTH AFRICA

Sources

For many years only small deposits of lead were known in South Africa of which few were mineable. These were principally replacement deposits associated with zinc and fluorspar occurrences in the dolomites of the Transvaal Supergroup in the Zeerust-Marico districts of the western Transvaal or vein and fissure occurrences which are widely spread over the central and eastern Transvaal. The most important of these deposits is that at the Argent Mine near Pretoria. More recently, important lead-zinc deposits, possibly of volcanosedimentary origin, have been found in the north-western Cape Province, east of Springbok. These deposits could make South Africa an important lead producer of the future.

Production

As a consequence of the small sporadic deposits, past lead production has been small but this is expected to improve considerably as the new major deposits are exploited. From 1940-1975,

an intermittent production of lead yielded a total of 18 971 tonnes as follows: 1941-1945, 4,75%; 1946-1950, 8,78%; 1951-1955, 18,78%; 1956-1960, 17,51%; 1961-1965, 1,20%; 1965-1970, 0,13% and 1971-1975, 48,85%. The average growth rate is +97,70% per annum (1940-1975), but this is probably unrealistic as it must omit rises from, and falls to zero production. A phenomenal growth rate of +383,64% per annum was recorded during 1972-1975, and during the latter year, the production was the highest ever (3 705 tonnes) which emanated from Prieska Copper Mines (Pty.) Limited as a byproduct ore.

Reserves, Resources

Lead resources prior to 1973 were probably very small but these have escalated dramatically with the discovery and evaluation (1974) of the Gams, Aggeneys and Zuurwater deposits. The resources of these deposits, in terms of tonnes of lead metal, are as follows:

Source	Deposit	Tonnes Metal	Resource
Rand Daily Mail, August, 1975	Aggeneys and Zuurwater (Broken Hill deposit)	3 063 000	Demonstrated
Coal, Gold and Base Minerals, April, 1974	Zuurwater (Black Mountain deposit)	2 082 000	Demonstrated
Rand Daily Mail, August, 1975	Aggeneys (Big Syn deposit)	724 000	Inferred
Coal, Gold and Base Minerals, April, 1974	Gams deposit	465 000	Demonstrated
Total:		6 334 000	

At the rate of the rather low 1975 production, the reserves should last for 1 757 years.

WORLD

U.S. Depletion Allowance

Domestic, 23%; foreign, 15%.

U.S. Prices

From 1961-1975, prices escalated at an average annual rate of 5,08% as follows: 1961-1965, +6,97%; 1966-1970, +0,40%; 1971-1975, +7,87%. The overall price during 1975 was estimated to be 21,60c per lb., representing a 4% drop from the previous year.

Production

The overall average rise in production from 1961-1975 was 2,50% per annum as follows: 1961-1965, +2,91%; 1966-1970, +4,71% and 1971-1975, -0,11%. World lead production in 1975 was 3,351 million tonnes from the following sources: Central Economy Countries (Bulgaria, Poland), 28,0%; other Market Economy Countries (Germany, U.K., France, Belgium, Italy, Netherlands, Denmark), 21,3%; U.S.A., 16,7%; Australia, 10,9%; Canada, 9,7%; Mexico and Peru, 5,3% each and other Latin American Countries, 2,8%.

Reserves, Resources

In 1950, world reserves were quoted at 40,823 million tonnes of metal which fell to 28,585 million tonnes (-30%) by 1963/1964. From that date the reserves grew at a rate of 34% per annum to 145,149 million tonnes of metal in 1975. The life of world resources at the 1975 production rate is 43 years. No resources figures are available but the prospect for discovery of additional resources at a rate that exceeds consumption, remains favourable. Low-tenor lead deposits have been recognized throughout the world and presumably will be explored eventually, thus more than doubling the present reserves. The following countries currently contain the world's lead reserves: U.S.A., 35,0%; Central Economy Countries, 20,6%; other Market Economy Countries, 15,6%; Australia, 11,6%; Canada, 10,0%; Mexico, 3,1%; Peru, 2,2% and other Latin American Countries, 1,9%. At present standing, South Africa's new demonstrated resources total 3,96% of world reserves.

EVENTS, TRENDS, OUTLOOKS

Domestic

As the new mines of the north-western Cape develop, there will be a considerable increase in production which should reach 350 000 tons per annum by the year 2000. At today's prices, this will be worth R155 million. Local sales of lead are not recorded but exports of lead in 1975 earned R160 286.

World

When economic recovery gets underway, no doubt there will be a strong and sharp improvement in demand for lead since consumers will wish to rebuild their commodity stocks and customers will want to replenish their supply of completed products. With supply and demand in better balance and stocks declining, a sustained growth in demand for the metal seems likely, with greater prosperity for its industrial manufacturers. The metal has withstood the recession better than most non-ferrous metals but it will require a greater effort by producers to stimulate consumption in a much more competitive market. One limitation to the growth of lead could be environmental considerations, especially on the use of lead as an additive to transport fuels in the U.S.A. Nevertheless the U.S. demand is expected to increase at an annual rate of 1,5% to 1980. There is great interest in the development of electrically-propelled vehicles in view of the energy crisis, so it is possible that this will create a big surge in lead demands for storage batteries and growth in lead consumption at the end of this century could possibly achieve about 4,5% per annum.

MANGANESE

General

Commodity Type

Manganese is rarely seen in elemental form but occurs mainly as a wide variety of supergene, metamorphic or hypogene minerals of which cryptomelane, psilomelane, pyrolusite (higher oxide), manganite, bixbyite, braunite, hollandite, hausmannite, jacobsite (medium to lower oxides), rhodochrosite (carbonate), and rhodonite (silicate) are the principal minerals. Nsutite or battery-grade manganese ore, occurs locally in a carbonate source. Most manganese is derived from open-cast mining, although some production accrues from underground mining of thick orebodies. Where necessary, simple concentration by washing, screening or jigging takes place to remove unwanted clay, sand or other contaminants. Deep-sea nodules are the most potential future source of the metal. Manganese ores, depending largely on their adaptability to use, are classified as metallurgical, battery and chemical grades.

Utilization

The three main categories of use are metallurgical, dry-cell battery manufacture and chemical, including miscellaneous. About 90% of manganese is used in steelmaking, primarily as the ferro-manganese alloy (78% Mn, 15-18% Fe), as "spiegeleisen" (15-20% Mn, rest iron), as silico-manganese (60% Mn; 12-20% Si) or as manganese metal. Ferromanganese accounts for 75% of consumption. Manganese is used in steel as a scavenger of deleterious sulphur and oxygen which make steel brittle, or as an alloy which makes steel more resistant to shock or abrasion. About 6,5-10 kg of manganese is consumed in a ton of steel. The other principal use is as a dioxide depolariser of dry batteries. Manganese has wide applications in the chemical industry. Ultimate use of manganese in the U.S.A. is in transportation, 21%; construction, 21%; machinery, 16% and other 42%. Seen from a consumption viewpoint, metallurgical uses account for 95%; chemical for 5% and other for 1% of available ores.

Geology, Exploration

Primary manganese deposits may be classified as sedimentary (including deep-sea nodules), volcanogenic or hypogene, with these types being to some extent intergradational. The sedimentary deposits are mostly of the commercial oxide type and the carbonate type. The latter are associated with strongly to moderate reducing sedimentary environments, while the oxide deposits occur under oxidising conditions. The older Precambrian manganese deposits are associated with iron-formation deposits. The deep-sea manganese nodules (with Cu, Co and Ni) are an enormous potential source of the metal. Many manganese deposits are associated with volcanic activity, overlapping into the sedimentary type, but deposits directly associated with volcanism are medium-sized at best. Hypogene ores are deposited from warm rising fluids, usually emanating from igneous terrains, with considerable replacement of amenable host rocks (dolomites, limestones) taking place.

According to the intensity, the black patination colour of manganese oxide is an excellent indicator of manganese deposits as a direct prospecting approach. The high variable background content of manganese in all rocks, soils and waters render geochemical methods difficult, if not unusable, but plants tolerant to manganese may be a useful pathfinder to such deposits. Those manganese deposits associated with ironstone are naturally easily found with ground or airborne magnetic methods. It should be cautioned that the surface expression of potential manganese ore-bodies may often be deceptively large and high-grade.

SOUTH AFRICA

Sources

In South Africa, the chief deposits of high-grade manganese occur within the Postmasburg and Kalahari fields. The orebodies occur either as sheetlike bodies at the unconformable contact between the Gamagara Formation and the underlying dolomites, or associated as lens-like bodies within the so-called Blink Klip Breccia; or occurring as thick bodies in the banded iron-formations as at Black Rock in the Kalahari field. Variable-grade (usually low) residual deposits of manganese occur locally in the dolomites of the western Transvaal and are used in the uranium industry. Many other smaller deposits are known in South Africa.

Production

South Africa produced 49 332 934 tonnes of manganese ore from 1941-1975 as follows: 1941-1945, 2,6%; 1946-1950, 4,5%; 1951-1955, 7,6%; 1956-1960, 9,0%; 1961-1965, 14,0%; 1966-1970, 20,2%; 1971-1975, 42,1%. The average production growth for the same period was 11,86% per annum as follows: 1941-1945, -18,37%; 1946-1950, +56,50%; 1951-1955, -5,08%; 1956-1960, +15,34%; 1961-1965, +5,81%; 1966-1970, +11,01% and 1971-1975, +17,79%. From 1953-1975, the ore produced had the following specification: <40% Mn., 57,6%; 40-45% Mn., 15,2%; 45-48% Mn., 10,2% and >48% Mn., 17,0%. The production during 1975 reached an all time high at 5 863 503 tonnes, showing a 22,3% increase over the previous year. This constituted 18,1% of world production.

Reserves, Resources

In 1950, the South African reserves were estimated at 45,359 million tonnes of 45% manganese. In 1959, the Postmasberg field was estimated to have reserves of 18,144 million tonnes of ore and the Kalahari field 63,503 million tonnes, a total of 81,647 million tonnes of ore, an increase since the previous estimate of about 20% per annum. Later internal estimates have been as follows (demonstrated resources):

Type	Tonnes	Source
High-grade >38%	50 000 000	Ortlepp, 1962
Medium-grade (no specs.)	320 000 000	Ortlepp, 1962, Coetzee, 1969
Low-grade ore (no specs.)	2 000 000 000	Coetzee, 1969
Total:	2 370 000 000	

Even later estimates (Brobst and Pratt, 1973) suggested reserves to be 3 000 million tonnes, conditional resources to be a possible 3 000 million tonnes and hypothetical resources a possible 2 000 million tonnes, a total of 8 000 million tonnes or 33% of the world's resources.

WORLD

U.S. Depletion Allowance

Domestic, 22%; foreign, 14%.

U.S. Price

Refers to metallic ore (46-48% Mn) per long ton unit of contained manganese, c.i.f., U.S. ports. The overall average price rose by 4,50% per annum from 1961-1975 as follows: 1961-1965, -3,40%; 1966-1970, -3,99% and 1971-1975, +20,89%. The price reached a peak (\$1,11) in 1974 but showed a slower rise (+27,03%) during 1975 (\$1,41) than the +60,86% rise during 1973/1974.

U.S. Import Sources

From 1958-1975, the average suppliers of manganese ore to the U.S.A. were as follows (trends shown in brackets): Brazil, 31,3% (34-22-35%); Gabon, 26,0% (25-18-31%); India, 7,6% (18-0%); South Africa, 7,3% (0-8%); Zaire, 2,8% (10-0%); Mexico, 1,6% (8-0%); Australia, 0,6% (0-9%); and other, 22,8%.

Production

The annual growth of world production from 1961-1975 was 4,00% as follows: 1961-1965, +6,86%; 1966-1970, +1,64% and 1971-1975, +3,49%. Provisional figures for 1975 indicated a world production of 22,498 million tonnes, to which the following countries contributed: Central Economy Countries, 44,3%; R.S.A., 18,1%; Gabon, 9,7%; Brazil, 8,1%; Australia, 7,3%; other Market Economy Countries, 6,5%; and India, 6,0%.

Reserves, Resources

In 1950 the world resources, at an average grade of +45% Mn ore, were 490,344 million tonnes and of 25% Mn average grade, 831,736 million tonnes. In 1973, the world reserves (unspecified grade) totalled about 6 500 million tonnes, conditional resources at 7 700 million tonnes and hypothetical resources at 10 000 million tonnes. The current (1975) world reserves are 5 379,6 million tonnes to which the following countries contribute: Central Economy Countries, 50,6%; South Africa, 37,1%; Australia, 5,6%; Gabon, 3,5%; Brazil, 1,6%; India, 1,1%; and other Market Economy Countries, 0,5%. At the present rate of world production, reserves should last for some 239 years.

TRENDS, EVENTS, OUTLOOK

Domestic

About 21,4% of manganese produced was consumed locally in 1975, the bulk by the ferromanganese industry but other important users were the uranium and electrolytic manganese industries. Ferromanganese production has increased rapidly and will continue to do so. In 1975, export sales of metallurgical grade manganese realised R82,6 million and local sales, R15,2 million. Although there has been a maintained rate of ore production, the outlook is for a reduction in consumption of 5% per annum from 1975 to the year 2000. The production rate is expected to be 20 million tonnes per annum by the year 2000, with a 1976 rand value of R4 000 million. Local ore processing is carried out on a relatively modest scale but because of soaring power costs overseas, there may be a marked increase in the production of local ferromanganese; 0,8 million tonnes by 1980, 1,0 million tonnes by 1985 and, with a growth pattern of 5% per annum, 2,0 million tonnes by the year 2000, which will have a 1976 rand value of R600 million. Also the local production of manganese metal is expected to grow to 45 000 tonnes by 1980 with a 4% annual growth to 98 000 tonnes by the year 2000 (1976 value, R70 million).

World

The fortunes of manganese ore producers are closely linked to those of the steel industry. World steel production is expected to increase at a rate of 5% per annum until the year 2000 and this may be considerably higher than the growth rate expected for manganese. The U.S. demand for manganese is expected to escalate through 1980 at the rate of 2% per annum, of which a small part may be supplied by stockpile excesses (76% excess out of 2 873 million tonnes, of which 13% is available for disposal). In the short term, manganese markets (ore and ferromanganese) are likely to remain highly competitive which may decrease with economic recovery. Although there are no substitutes for manganese in its principal use, no supply shortage is foreseen. The manganese nodules of the ocean floor present the greatest economic threat to current producers, but the legality of ownership of these reserves will probably remain contentious. Nevertheless resources on land are more than adequate for the rest of this century.

NICKEL

General

Commodity Type

Nickel is estimated to be the fifth most abundant element on earth as a whole, although its presence in the outer crustal shell is limited to mafic and ultramafic igneous rocks intruded into the crust from the mantle where nickel is a major constituent. The most common ore minerals are pentlandite $(Fe.Ni)_9S_8$ in sulphide ores and garnierite (nickel-magnesium hydrosilicate) in secondary ores especially of the lateritic type. Nickel also substitutes for iron in the sulphide minerals pyrrhotite and pyrite.

Primary smelter and refinery products are chiefly the metal (99,95% electrolytic cathodes, ingots, shot, briquets, pellets, powder); the oxide (powder, sintre) and ferronickel (cast as 50 lb. pigs with 40-50% Ni; 49-59% Fe; 0,5% cobalt; 0,1% Cr; 0,05% P; 0,015% C; 0,010% S; and 0,3% Cu).

Utilization

Nickel is a vital element in the economic welfare and security of the industrial nations of the world. The chief uses are in steels, 40%; alloys, 36%; electroplating, 16%; castirons, 3%; chemicals, 1%; and other 4%. U.S. uses in 1975 apart from steel, included transportation, 22%; chemical, 15%; electrical, 12%; and construction 10%. Nickel is finding increasing application in coinage, either in its pure state or alloyed with copper and most countries now utilize nickel in coinage denominations. It is also used in space-craft, atomic installations and jet engines where high temperatures prevail and new uses are continually being found for the metal, especially in the production of new alloys.

Geology, Exploration

Sulphide deposits are by far the most important present sources of nickel, both with regard to the quantity of contained nickel and the number of deposits. These deposits always occur associated with igneous rocks, especially with ultrabasic types at the base of layered intrusions although their occurrence with intermediate rocks especially in the world's major source (Sudbury, Canada), are manifest. Another major source of nickel is the ultramafic lavas (komatiites) and sills occurring within the Archaean greenstone belts of the world. Hydrothermal veins are an unimportant source of nickel sulphides. An important nickel resource is contained in lateritic mantle cappings formed by the weathering of peridotites, dunites, serpentinites and pyroxenites under tropical to sub-tropical weathering environments but the ores (up to 1,5% Ni) are difficult to treat. A major unexplored source are the nickel-bearing manganese nodules contained on the deep ocean floors (0,1-1,1% Ni).

Prospecting and exploration techniques commonly used are remote sensing methods (lineaments from satellite imagery and aerial photographs), the incidence of magnetic and electromagnetic anomalies, geological and geochemical methods. The methods are different from different classes of deposit. The lateritic ores involve geological search for weathering surfaces overlying favourable rocks under tropical to sub-tropical climatic conditions with geochemical follow-up.

SOUTH AFRICA

Sources

Only limited mining of nickel as a primary product has taken place, so that nickel production stems mainly from a byproduct to platiniferous mining. Limited ore occurrences are in the nickel pipes in the Bushveld Complex west of the Pilanesberg, at Insizwa and at Pafuri and Klein Letaba. The serpentinites especially, in the Barberton area, may represent a future source of the metal.

Production

Unfortunately the production record is incomplete as no figures were published from 1957-1969. From 1939-1956, a total of 17 343 tonnes of ore was produced. The annual rate of production increased considerably: from 1939-1945, the average annual production amounted to 500 tonnes per annum; from 1946-1950, 638 tonnes per annum and from 1951-1956, 2 012 tonnes per annum. The average annual growth rate was 12,57% per annum (1940-1945, +0,66% per annum; 1946-1950, +12,84% per annum and 1951-1955, +23,15% per annum). By contrast, during 1970-1975, the total production was 98 240 tonnes at an average annual rate of 16 373 tonnes, an average annual growth rate of 15,18%. Production in 1975 amounted to 20 754 tonnes, down 6,09% from the previous year.

Reserves, Resources

In 1971, South African resources from unidentified localities, stood at 2,44 million tonnes of metal. In 1973, the ore resources were thought to total 200 million tonnes at 1% nickel (2,0 million tonnes of metal). Up-to-date identified resources figures of nickel metal (1975) are as listed in the table which follows. It should be noted that the calculations of the Merensky Reef and UG2 Reef assumes a strike length of 230 kilometres to a vertical depth of 1 200 metres (MR 0,8 m stoping width, 3,2 t/cu. metre; UG2 0,9 m stoping width, 4,3 t/cu. metre). The Platreef of the Potgietersrus area was assumed to have a 25 metre thickness over 30 km to a depth of 1 200 metres. The nickel pipes, because of their very small dimensions (ca 3 m diameter), contain conditional reserves.

Hypothetical resources of nickel ore are contained in the limonitic birbirite ores west of the Pilanesberg. The ores occur over several square kilometres and tonnages could be of the order of 2,67 million tonnes per square kilometre. The tenor of ore is low; average 0,16% Ni but can be as high as 0,4% Ni.

Area	Grade	Recoverable	Metal Resources million tonnes	Reference
Merensky Reef	0,18%	1,3 kg/ton	4,3	Von Gruenewaldt, 1976
UG2 Reef	Variable	0,7 kg/ton	3,8	Von Gruenewaldt, 1976
Platreef	Variable	3,6 kg/ton	14,7	Von Gruenewaldt, 1976
Nickel Pipes	1,56%	--	0,003758	Vermaak, 1976
Total:			22,803758	

Current identified resources may be as high as 42% of current world reserves. At current production, the identified resources should last for at least 1 000 years.

WORLD

U.S. Depletion Allowance

Domestic, 23%, foreign, 15%.

U.S. Prices

The price has escalated at an average rate of 7,36% per annum since 1960 as follows: 1960-1965, +1,09%; 1965-1970, +10,78% and 1971-1975, +10,21%. The average 1975 price was 210,5 U.S. cents/lb., f.o.b. Canadian ports, having shown a 18,92% rise since the previous year.

U.S. Import Sources

During the period 1958-1975, Canada supplied an average of 86% (91-68%) of the U.S. nickel imports. The figures in brackets refer to the trends during that period. Norway, 8% (7-10-8%); Cuba, 1% (13-0%); New Caledonia, 0,6% (0-6%); Dominican Republic, 0,4% (0-5%) and others, 4%, augmented the U.S. imports.

Production

World nickel production escalated by 5,55% per annum since 1961 as follows: 1961-1965, +4,56%; 1966-1970, +8,25% and 1971-1975, +3,83%. The sources of 1975 production were as follows: Canada, 34,7%; other Market Economy Countries, 24,3%; Central Economy Countries, 17,7%; New Caledonia, 17,0%; Cuba, estimated 4,3%; and U.S.A., 2,0%. The metal production in 1975 amounted to 745 252 tonnes, thereby showing a small drop of 0,51% over the previous year.

Reserves, Resources

In 1950, the world resources of nickel metal totalled 14,061 million tonnes. In 1973, a detailed estimate of identified resources was undertaken showing the following position (tonnes metal):

Country	Sulphide Ores	Country	Laterite Ores
Canada	17 900 000 (46,6%)	Cuba	20 000 000 (38,3%)
U.S.A.	14 490 000 (37,7%)	New Caledonia	9 000 000 (17,2%)
Australia	3 300 000 (8,6%)	Phillipines	8 000 000 (15,3%)
R.S.A.	2 000 000 (5,2%)	Indonesia	4 500 000 (8,6%)
U.S.S.R.	600 000 (1,6%)	Guatamala	1 500 000 (2,9%)
Other	95 000 (0,3%)	U.S.S.R.	1 500 000 (2,9%)
		Other	7 746 500 (14,8%)
Total:	38 385 000	Total:	52 246 500

giving total identified ore resources as 90 631 500 tonnes.

Actual reserves in 1975 were stated to be 53,977 million tonnes metal in ores with a grade varying between

0,2 to 4,0% Ni, resources as 63,503 million tonnes of metal (sulphide and laterite ores of +1% grade), with peridotites and serpentinites containing 0,2-0,4% nickel being several orders of magnitude greater than the known resources.

TRENDS, EVENTS, OUTLOOK

Domestic

The current byproduct production of nickel metal is about 20 000 tonnes per annum and is valued at about R80 million. This should increase to 40 000 tonnes per annum by the year 2000 at a 1976 rand value of R150,0 million. Other sources suggest that production may be as high as 120 000 tonnes. The main local consumption is in stainless steel and in the production of nickel-magnesium alloy. Stainless steel production is currently 20 000 tonnes per annum and is expected to grow rapidly towards the end of the century.

World

World nickel consumption from 1963-1974 grew at an annual rate of 6%. Stainless steel production (41% of the total market) showed an 8% annual growth over the last 15 years, thereby exceeding all other market products (share of market: electroplating, 16%; high-nickel alloys, 12%; structural steel alloys, 10%; cast-iron and steel, 9%; copper and brass products, 3% and others, 9%). Stainless steel consumption is expected to grow at 7,5% per annum to 1980 and thereafter by 6,5% per annum to the year 2000. Consequently it is expected that the overall nickel consumption will decrease to 5% per annum between 1975 and the year 2000 (world consumption, 2,3 million tonnes).

There are other important trends in nickel demand: (1) Tendency to use lower grade nickel because of improvements in stainless steel production techniques and (2) Japan has replaced the U.S.A. as the largest stainless steel producer with further geographical changes possible.

U.S. demand for nickel is expected to increase at an annual rate of 3% until 1980. The worldwide recession, which hardly affected the nickel industry in 1974, showed far harsher effects in 1975 and stood in stark contrast to record production and sales during 1974. Thus 1975 proved to be the year in which sales dropped, inflation sent costs soaring and producer inventories increased, the stocks being double of what producers would have chosen them to be. Moreover, the magnitude of current capitalisation to bring new projects to fruition, curtailed potential producers from opening new mines especially on lateritic nickel (Indonesia, Guatemala, New Caledonia, Greece). Nevertheless, more favourable government outlooks in Australia and Canada boded well for the future so that producers problems looked somewhat brighter in 1976 and the indications are that matters will improve considerably in the nickel field unless the recession holds.

PETROLEUM

GENERAL

Commodity Type

Petroleum, crude oil or rock oil are natural fluids composed predominantly of compounds of hydrogen and carbon. Many independent lines of evidence indicate that these commonly complex hydro-carbon chemical compounds are ultimately of biological origin. Crude oil has been sold on the basis of gravity with the more versatile and volatile lighter oils (gasoline, light distillate) being worth more than the heavier oils. Deleterious constituents are sulphur and salt and other substances (nitrogen compounds, arsenic, vanadium and other minerals and metals) that poison cracking and reforming catalysts. Sulphur content can also be a quality criterion in sales. Elaborate price scales for crude oils, which take cognisance of quality and location, have been established all over the world. Most quantities in the petroleum industry are measured in barrels, the most common being the U.S. barrel containing 42 U.S. gallons and weighing 310 lbs.

Utilization

The principal uses of petroleum are to produce heat and power. Crude petroleum is the feed-stock of refineries which produce a host of products, the major types being motor, aviation, domestic and industrial fuels. About 90% of the 5 000 petroleum products is gasoline and fuel oils. The output of all refineries in the U.S. in 1963 provide some idea of these product proportions: gasoline, 47,8%; distillate fuel oil, 22,7%; residual fuel, 8,2%; kerosene (paraffin), 4,9%; asphalt and road oil, 3,5%; military jet fuel, 2,9%; petrochemical feedstock, 2,7%; coke, 2,4%; lubricants, 1,9%; wax, 0,2% and miscellaneous, 2,8%. In the United States, motor fuel (gasoline) is sold as two octane gradings. There are five grades of aviation gasolines, three grades of jet fuels, three standard diesel fuels and five standard grades of fuel oil. A large part of the kerosene (paraffin) is burned as commercial

jet aircraft fuel (1963, 44%). Thus power for almost every kind of transportation on land, sea or air is, or can be, supplied by burning petroleum fuels. Petroleum coke is burned in a few large utility furnaces and some is sold as briquets. The petroleum industry is large and organised and depends on large-volume operations to be economically successful. Ultimate consumer uses in the U.S.A. in 1975 were: transportation, 54%; household and commercial, 18%; industrial, 19%; electrical generation and utilities, 9% and of refinery products were fuels, 88%; petrochemical feedstock, 7%; asphalt and road oil, 2% and miscellaneous, 2%. The petroleum refining industry, through continuous development, has continued to meet changing demands by the evolution of new processes (atmospheric distillation, thermal and catalytic cracking, alkylation, chemical treatments and solvent refining) involving steady progress in application of science, technology and engineering.

Geology, Exploration

Hydrocarbon compounds have been found in almost all rocks dating from the Precambrian but their frequency of distribution increases with progressive younging of sediments as follows: Pre-Permian, (510-250 million years old), 6%; Permian (225-200 million years), 8%; Mesozoic, (200-74 million years), 57% and Cenozoic (74 million years to present), 29%, based on world distribution. Based on worldwide cumulative production figures, the distribution is 24,4%; 4,7%; 21,5% and 49,4% respectively. Organic carbons and hydrocarbons show extremely erratic distribution in unmetamorphosed sedimentary rocks but within Holocene sediments, they are generally more abundant in marine silts and clays deposited rapidly in basins or depressions or on the edges of continental shelves especially in brine-rich waters. They decline rapidly in abundance in coarser sediments. The general rule is that vast quantities of geologically younger petroleum are characteristic of the more recent geological environment, that is, the last one-eighth to one quarter of the earth's history; but oil can appear in unexpected places. Other empirical rules which determine petroleum distribution are that the quality and quantity are distinctly dependent on reservoir depth. Low-density crudes occur in the lower reservoirs in older rocks, heavy crudes occur in shallower and younger rocks. Quantity is depth-dependent as follows: less than 500 metres depth yields 6,9% of total production volume; 500-1 000 metres, 32,3%; 1 000-1 500 metres, 25,1%; and over 1 500 metres, 34,7% while little oil occurs deeper than some 4 250 metres, due especially to decrease in rock porosity at that depth. Once formed, numerous agents acting independently or collectively tend to cause migration of the fluid hydrocarbons from their fine-grained source rocks to coarser-grained or fractured rocks having the physical characteristics of reservoir rocks below suitable traps. The more important of these agents are increasing rock temperature and decreasing pore space in subsiding basins which establish pressure and temperature gradients along which pore water and entrained or diffused mobile hydrocarbons tend to migrate towards the surface. If no trap exists where the migrating fluids can attain a semi-stable state of lowest potential energy, the fluids reach the surface and are lost by evaporation to the atmosphere. There are an infinite variety of potential traps with suitable geometry to serve as impediments or impermeable barriers to oil migration, the most common being anticlinal domes, arches or folds capped by shale, anhydrite, gypsum or any rocks impermeable to fluid penetration.

The earliest method of search relied on finding oil and gas seeps in low-lying ground ("creekology"), but later wildcatting also recognised the crests of rock-layer anticlinal folds as favourable structures. Perhaps the most useful of the latter instrumental methods was reflection seismography in which artificially-created shock waves are reflected from subterranean rock strata and recorded through geophones onto magnetic-tape recorders, transistor-electronic systems and high-speed automatic computers, combined with a wide variety of data-processing techniques on surface. Because of the high cost of this method, it is confined to very favourable areas indicated by the cheaper magnetic and gravity methods of regional search. The latter instruments have also been successful in contouring the basement below favourable sediments and in locating anhydrite, gypsum or salt beds and domes with a gravity differential compared with their surroundings. A more recent geochemical innovation is the search for hydrocarbon anomalies by investigating soil-gas contents of samples collected on grid patterns. But, as in most exploration, the indirect survey methods of geochemistry and geophysics, and to some extent geology, do not actually indicate the presence of oil, so that only drilling can establish its presence. The amount of drilling done for oil is phenomenal - in the United States alone, more than 2 222 300 wells totalling over 2 133,6 million metres of drilling had been completed by the end of January, 1973. Greater usefulness of drilling completed is now achieved by using resistivity and self-potential electrical well logging, microcaliper logging of holes and other structural measurements. A new innovation is the use of electrically-fired, explosive-propelled corebarrels.

SOUTH AFRICA

Source

In spite of some reasonable indications of gas and crude petroleum in onshore but especially offshore recent marine rocks, South Africa currently has no exploitable oil. Since 1965 the Southern Oil Exploration Corporation (Pty.) Limited (SOEKOR) has been engaged along with numerous concession-holders in the search for oil. From 1965-1973, 91 wells had been completed at a cost of \$110 million, to which SOEKOR contributed about half that amount. SOEKOR had contributed R95,14 million by the end of 1974. The limited successes indicated include signs of oil in the Colchester well drilled in the Cretaceous Algoa basin on land and gas finds (15 km³) in 1969 and oil indications in 1976 off Plettenberg Bay. The search continues.

Imports

Local data on oil imports appear to be classified information for strategic reasons. Some idea of imports for the years 1962-1972 are provided by the U.S. Minerals Yearbook. The importation of crude oil amounted to 566,345 million barrels, of which 37,9% was imported during 1962-1967 and 62,1% was imported from 1968-1972. At the same time, 61,250 million barrels of gasoline were imported, 69% during 1962-1967 and 31% from 1968-1972, the drop reflecting the increasing fuel production from local refineries. Overall annual growth of crude petroleum imports averaged 27,88% (1962-1967, +50,19%; 1968-1972, +5,57%) while imports of gasoline decreased at an average 10,07% per annum (1962-1967, -15,88%; 1968-1972, -4,27%). After 1972, serious price increases have occurred so that from July 1972, where the internal price of gasoline was 9,9c per litre, this has escalated almost three times to a price of 27,6c per litre in January, 1977; although some portion of the increase represents funding of the Sasol II project (see Coal).

The annual imports of crude petroleum in 1975 have been estimated to be 22 000 megalitres or 138 374 870 barrels. This represents an increase of 161,19% from 1972 or +53,73% per annum. The landed cost is estimated to be 7 cents per litre (after 1975 devaluation and increase during September 1975), so that total imports in 1975 cost the country an estimated R1 540 million. The stockpile was estimated to be 25 000 megalitres (157 244 171 barrels) in 1975 and the consumption was estimated at 17 500 megalitres (110 070 920 barrels) of which Sasol contributed 3,71% or 650 megalitres (4 088 348 barrels). Customs and excise duty in 1975 was 5,325 cents per litre of which 2 cents was allocated to the Strategic Oil Fund (Financing of Sasol II) and 2,004 cents to the National Roads Fund. To streamline transportation, a pipeline for refined products and a separate one for crude oil were constructed in 1965 at a cost of R80 million, which during 1974/1975 showed a profit of R84,4 million (revenue R97,2 million, working expenditure, R12,8 million).

Reserves, Resources

South Africa has no crude petroleum resources but obtains some of her fuel requirements from oil-from-coal plants (see Coal; also Trends, Events, Outlooks).

WORLD

U.S. Depletion Allowance

With limitations, 22%.

U.S. Prices

Prices escalated at an average of 7,82% from 1961-1975 as follows: 1961-1965, -0,14%; 1966-1970, +2,16% and 1971-1975, +21,44%. The bulk of the meaningful escalation happened during 1972-1973, +14,75%; 1973-1974, +76,09% and 1974-1975, +9,78%. The average U.S. price per 42 gallon barrel at well head during 1975 was \$7,52.

U.S. Import Sources

The countries supplying oil to the U.S.A. (1958-1974) were as follows with the trends indicated in brackets: Venezuela, 31,3% (51,12%); Canada, 28,6%; Kuwait, 7,7% (17-0%); Saudi Arabia, 6,6% (7-9-11%); Libya, 1,8% (7-0%); Indonesia, 1,8% (7-0%); Nigeria, 1,7% (0-14%) and Iran, 0,5% (6-0%). In 1975, Africa became the largest regional source of U.S. crude petroleum imports, replacing Canada.

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... demand for this commodity. The average annual growth rate from 1941-1975 was 6,58% as follows: 1941-1945, +4,07%; 1946-1950, +8,07%; 1951-1955, +8,20%; 1956-1960, +6,47%; 1961-1965, +7,54%; 1966-1970, +8,61% and 1971-1975, +3,14%. During 1967-1975, U.S. annual production average fell by 0,58%. In 1975, world production was 19 300 million barrels to which the following countries contributed: Other Market Economy Countries, 38,4%; U.S.S.R., 18,7%; U.S.A., 15,8%; Saudi Arabia, 13,3%; Iran, 10,3%; and Central Economy Countries, 3,5%.

Reserves, Resources

In 1975 the world reserves of crude oil were estimated to be 712 350 million barrels, to which the following countries contributed: Other Market Economy Countries, 47,1%; Saudi Arabia, 23,1%; U.S.S.R., 11,7%; Iran, 9,3%; U.S.A., 4,8%; and other Central Economy Countries, 4,0%. From 1941 to 1974, U.S. oil reserves escalated at 2,02% per annum as follows: 1940-1950, +3,30%; 1951-1955, +3,53%; 1956-1960, +1,06%; 1961-1965, +0,30%; 1966-1970, +5,21% and 1971-1975, +2,55%. At the present production

rate, the U.S. reserves have an apparent life of 11,2 years and those of the world, about 37 years, although estimates of potentially recoverable petroleum resources vary from between 2,0 and 4,5 trillion (U.S.) barrels.

TRENDS, EVENTS, OUTLOOKS

Domestic

South Africa has lived for a long time under the cloud of possible oil embargoes or sanctions. She has sought to counter the possibility by increasing her storage capacity, increasing pipeline facilities for oil transportation and increasing her oil-from-coal capacity. Nevertheless these plans are being hampered by increasing oil imports and refinery outputs (1972 refinery consumption 242 600 barrels per day; 1973, 331 000 barrels per day; an annual increase of 36,4% with greater capacities planned for the future), the increasing burden of escalating oil prices over which she has no control and the escalating capitalisation costs of projects aimed at lessening dependence on outside sources. Thus although the SASOL expansion was originally thought to be able to cope with 40% of the country's liquid fuel requirements at a capital cost of R1 900 million, latest projections are that this will supply only 28% of the country's needs at a capitalisation of R2 500 million. Under such circumstances of uncertainty, the validity of prediction becomes highly suspect. It has nevertheless been predicted that the market share of oil will decrease from 23,7% in 1973 to 16,4% at the end of the century, implying a twofold increase of oil imports compared with the 1973 level.

World

The whole pattern of oil production and supply started with the sharp price escalation by the OPEC cartel in 1973. Compared to the earthquake proportions of this event, events in 1974 and 1975 were only major after-shocks in the world oil industry. The trend is for the Middle East countries to nationalise all oil holdings within their borders, to keep escalating crude oil prices and to increase the OPEC oil income in the years ahead. There is even a move afoot to dismantle the larger U.S. oil companies for state control. Under such uncertain conditions, the future of petroleum appears to be fluid especially as the world has been slow in reacting to the existing trends or of finding alternate sources of power for transportation and industrial needs.

PHOSPHATES

GENERAL

Commodity Type

Phosphorous is one of the three elements vital to plant growth and it is less abundant than the other two, nitrogen and potassium. The principal minerals of phosphate deposits are apatite and phosphorite (impure to pure phosphate of lime in combination with iron and aluminium). Phosphate rock refers to any rock containing more than 20% P₂O₅ although commercial deposits usually contain not less than 28-30% P₂O₅ with not more than 3-4% combined iron and alumina oxides. The optimum amount of lime (calcium carbonate) allowable is about 5% but deposits often contain considerably more. Phosphorite is an equivalent to phosphate rock but usually refers to marine deposits. Ordinary superphosphate is the product of treating phosphate rock with sulphuric acid to make the phosphate more soluble and available. Triple or treble superphosphate is made by mixing phosphate rock with phosphoric acid.

Utilization

Phosphates are used chiefly in fertilizer manufacture. Other uses are many, including animal feed supplements, detergents, electroplating and metal polishing, insecticides, medicines and incendiary bombs. The chief uses in the U.S.A. during 1975 were in fertilizers and animal feed supplements (85%) while the balance was used in industrial and food-grade products. Elemental phosphorous and phosphoric acid are used to make inorganic to organic chemicals which are used as leavening agents, water softeners, cleansing products, soaps, plasticizers, insecticides and many other purposes. Elemental phosphorous is used for smokescreen and incendiary bombs, pesticides and phosphorous alloys. Phosphoric acid is used in beverages and ceramics, as oil catalysts and refining agents, in photography and in dental and silicate cements.

Geology, Exploration

Phosphates are found in mineable concentrations in three principal environments - guano or deposits derived from guano, igneous apatites and marine-phosphate deposits. All other deposits are secondarily derived. The largest deposits are those in which apatite occurs as a minor constituent within major igneous masses such as in intermediate or alkaline igneous rocks. Such deposits yield about 17% of world production. Guano deposits or deposits derived from guano-derived waters infiltrating favourable (limestone) hosts are usually small and provide only about 1% of world production. The major world supplier (75%) are sedimentary phosphorite deposits which form under warm marine conditions or under coastal upwelling conditions isolated from clastic sedimentation. A major consideration for testing the viability of phosphate deposits, is the transportation of a bulk, low-value product to areas of manufacture. Phosphate deposits should always be tested for potentially economically recoverable amounts of vanadium, uranium and rare earths.

Search for marine phosphate deposits revolve around finding the correct depositional environment for such deposits. Phosphorite is not a distinctive rock and can easily be overlooked or mis-identified. Particularly sensitive geochemical techniques for locating phosphatic rocks are known. Indirect radiometric methods can be used as many deposits have a radioactive response and can, like geochemistry, be used to test favourable sedimentary rocks or igneous rocks of the correct type.

SOUTH AFRICA

Sources

Three classes of phosphate deposits occur in South Africa: those of igneous origin, those derived from phosphatic sediments and those of metasomatic origin which derive their phosphate content from the percolation of phosphate-bearing waters. Most important of the first type are those associated with the Loolekop carbonatite near Phalaborwa, although other carbonatites (Glenover, Spitskop), basic igneous rocks (Bushveld Complex) and pegmatites (near Bandolierkop station, Soutpansberg) are known to contain apatite. Metasomatic deposits are veinlike deposits associated with dykes (Potgietersrus and Middelberg districts) and replaced recent limestones, calcareous sands or nodules in the Saldanha and Mamre areas of the Cape. Sedimentary phosphates in the Karoo sediments occur in the southern Karoo and in Natal. Although it is no longer produced in quantity, guano was for a considerable period the only local phosphate supply but was replaced by the aforementioned sources. South Africa has recently become an important producer of phosphoric acid (capacity, 1 000 tonnes per day).

Production

From 1946-1975, South Africa produced 36 566 161 tonnes of crude phosphate ore as follows: 1946-1950, 0,6%; 1951-1955, 1,4%; 1956-1960, 2,8%; 1961-1965, 6,2%; 1966-1970, 20,1% and 1971-1975, 68,9%. This clearly illustrates the rapid growth of the production in recent years. The average annual production rate has increased by 25,74% per annum (1946-1975) as follows: 1946-1950, +10,02%; 1951-1955, +25,72%; 1956-1960, +13,54%; 1961-1965, +9,01%; 1966-1970, +26,31% and 1970-1975, +69,83%. The greatest increase was 279,31% during 1974 compared with 48,59% during 1975. Production during 1975 was 11 626 130 tonnes.

Reserves, Resources

In 1959 the total phosphate (P_2O_5) reserves stood at 2 668 692 tonnes (Palabora, 94% Langebaan, 5,7%; Potgietersrus, 0,3%) but these have increased to over one thousand million tonnes at present. These are made up as shown in the table on the following page. At the current production rate, the resources should last for about 90 years. The proportion of domestic reserves as a function of world reserves is about 6,5%.

WORLD

U.S. Depletion Allowance

Domestic and foreign, 15%.

U.S. Prices

U.S. prices rose an average of 11,86% per annum from 1961-1975 as follows: 1961-1965, +4,83%; 1966-1970, -2,38% and 1971-1975, +33,14%. The rises over the last two years have been dramatic (1974, +92,93%; 1975, +64,83%) to \$18,00 per short ton, f.o.b. mines in 1975, pointing to strong demand for the commodity. World-wide the demand rose by an amazing 12% in 1975, notwithstanding an increase of 200% in export prices in some quarters, notably Morocco. This position could not last and a drop of between 4 and 9% in demand has been recorded during the latter half of 1975/early 1976 (see Outlook).

Area	Ore	% P ₂ O ₅	P ₂ O ₅	Source
<u>Demonstrated Resources:</u>				
Palabora, S. pyroxenite	363 million tons/ 100 ft.	6%	21,780 mill. tons.	Hanekom, v. Staden and others, 1965
Palabora, S. pegmatoid	No data			
Palabora, N. pyroxenite	Several thousand million tonnes	6%	--	ditto
Foskorite (West portion)	77,100 million tons/ 152,5 m	10-12%	8,481 mill. tons.	ditto
Carbonatite	28,000 million tons/ 1 000 m	37%	10,360 mill. tons.	ditto
Total Palabora	at least		40,621 mill. tons.	
<u>Resources:</u>				
Total Palabora	2 800 million tons/ 1 000 m depth	37%	1 036 mill. tons.	Foskor, 1974
Glenover carbonatite	10 million tons.	35%	3,500 mill. tons.	Verwoerd, 1967
Western Cape	35,0652 million tons.	31%	10,8702 mill. tons.	
Schiel	30 million tons.	5,1%	1,530 mill. tons.	Foskor, 1968
Grand Total	2 875 million tons.		1 052 mill. tons.	

U.S. Import Sources

During 1958-1974 the U.S. import sources were as follows (figures in brackets show trends): Netherlands Antiles, 75,6% (88-57%); Mexico, 16,5% (12-5-24%); Togo, 4,1% (5-29-0%); Spanish Sahara, 1,8% (0-13%); Morocco, 0,6% (0-3%); Israel, 0,4% (0-6%) and other, 1%.

Production

World phosphate production rose by an average 8,20% per annum from 1961-1975 as follows: 1961-1965, +10,26%; 1966-1970, +9,74% and 1971-1975, +4,60%. The following countries contributed towards the 1975 production of 105 868 460 tonnes: U.S.A., 42,0%; Central Economy Countries, 25,7%; Morocco, 12,8%; other Market Economy Countries, 11,1%; Tunisia, 2,6%; Spanish Sahara, 2,6%; Togo, 1,7%; Senegal, 1,3% and Australia, 0,2%. It seems strange that South African production (about 11% of world production) does not figure in the listing in the source used.

World Reserves

In 1950, world reserves were estimated to be 30 844,28 million tonnes. In 1973 identified resources of contained phosphorous were 6 000 million tonnes with 9 000 million tonnes as hypothetical resources. In terms of contained P₂O₅ content, these figures are 13 746,96 and 20 620,44 million tonnes respectively. In 1975, reserves of marketable phosphate rock (no P₂O₅ content quoted) was 16 066, 242 million tonnes, to which the following countries contributed: Morocco, 56,5%; U.S.A., 14,1%; Spanish Sahara, 9,6%; Australia, 5,6%; Central Economy Countries, 5,3%; other Market Economy Countries, 5,1%; Tunisia, 2,8%; Senegal, 0,7% and Togo, 0,3%. Most of the world resources are widely distributed as marine phosphorite deposits and identified resources are measured in tens of thousands million tonnes, with hypothetical resources many times as great. Phosphate rock contains substantial amounts of fluorine and potentially economically recoverable amounts of vanadium, uranium and rare earths.

TRENDS, EVENTS, OUTLOOKS

Domestic

Local sales of phosphate have increased by an average rate of 9% per annum over the last 8 years. In 1975, total sales of phosphates realised R24 812 461 of which almost 99% was consumed locally. Dramatic increases in prices of phosphates and phosphatic fertilizers have encouraged the development of ambitious export projects. Foskor has been increasing capacity from 1,1 million tonnes to 2,0 million tonnes by the end of 1975 and 2,75 million tonnes at the end of 1976. With the export drive planned, in which Foskor will be exporting phosphate concentrate direct, production is projected to increase to 7,5 million tonnes by 1980 and, with a 7% increase per annum, to reach 30 million tonnes by 2000 (1976 rand value R580 million).

World

Due mostly to large reserves of phosphate rock built up as a hedge against inflation, a surplus of phosphate rock has built up. This was caused also by consumer resistance to high prices of phosphate fertilizer during 1975. This has created considerable uncertainty regarding outlooks for phosphate production. The short and long term demand for phosphate rock is nevertheless expected to increase at 3% per year in the U.S.A. and between 5% and 6% in the world for the rest of this century. This is linked to the world demand for food, commensurate with population gains. Although attempts are being made to restrain progress of new mining projects, the prices generally are attractive enough to warrant prospecting for new reserves or evaluating previously unattractive reserves.

PLATINUM - GROUP METALS

GENERAL

Commodity Type

Platinum and palladium are the most abundant platinum-group metals (PGM) while iridium, osmium, rhodium and ruthenium are the less abundant metals. The PGM (sometimes with mercury) are major constituents of high-temperature magmatic minerals (with anions of sulphur, antimony, arsenic, bismuth and tellurium) and high-temperature magmatic alloys (with iron, gold, cobalt, copper, lead, nickel and tin). Derived and hydrothermal ores are mostly enriched in the light PGM (palladium, rhodium, ruthenium) while selective leaching in placers and sedimentary ores leaves a residue enriched in the heavy PGM (osmium, iridium and lesser platinum). The most common minerals are braggite (platinum, palladium, nickel sulphide), cooperite (platinum sulphide), laurite (sulphide of Ru, Ir, Os) and sperrylite (platinum arsenide) which exist either as discrete minerals or occur in complex intergrowths with each other or, more commonly, with the most common alloy, platinum-iron alloy. A host of minor minerals (mostly bismuthotellurides such as moncheite, merenskyite, kotulskite and michenerite) and minor alloys (palladic electrum, arsenopalladinite, stibiopallainite, atokite, paolovite, rustenburgite etc.) occur as rare constituents in magmatic ores. Osmoridium is the most common mineral in placer ores. Normally the metals are produced at high purity, more than 99,99% pure.

Utilization

The industrial use of PGM is based on their catalytic properties, their electrical conductivity and their resistance to heat, oxidation and chemical corrosion. As such, their use is manifest: (1) in the petroleum refining industry as a catalyst to produce high-octane automotive fuels, (2) as a converter of noxious exhaust gases, (3) as a catalytic gauze for the oxidation of ammonia and the manufacture of nitric acid by the chemical industry, (4) by electrical manufacturers as electrical contacts in precision instruments and insoluble anodes for metallurgical processing, (5) in dental and medical devices and instruments, (6) as nozzles and spinnerettes used in glass and synthetic-fibre manufacture, and (7) in decorative arts and jewellery. Consequently the use in the U.S.A. during 1975 has been estimated at chemical, 28%; automotive, 27%; electrical, 24% and other, 21%.

Geology, Exploration

Workable PGM deposits fall into two major classes: magmatic, associated with nickel-copper or copper ores in mafic to ultramafic intrusions; or sedimentary placer deposits. The magmatic deposits can be subdivided into three main types: (1) in layered igneous complexes - mineralized, mostly chromite-bearing stratiform layers in floored tabular complexes consisting of cyclical magmatic sedimentation of cumulus minerals; (2) in concentrically-zoned complexes - mineralized layers in roughly cylindrically-zoned complexes formed by sedimentary, metamorphic or igneous processes; and (3) in irregular Alpine-type complexes - lenticular discordant layers or pods with a tectonic fabric. The first type occur in shield areas, the second in mobile-belt metamorphic terrains and the third in eugeosynclinal orogenic belts and island arcs. The sedimentary deposits have derived their PGM from mafic to ultramafic source rocks and consist of ancient lithified to recent unconsolidated gold-placer deltas; alluvial, terrace or beach deposits and glacio-fluvial outwashes.

All prospecting for the platinum metals has been, and continues to be, somewhat intuitive. Early discoveries of PGM deposits was done by the prospecting pan although latterly limited attempts have been made to prospect geochemically by searching for tracer elements commonly associated with known deposits. In fact, many sulphide deposits are found to be platiniferous only after their location by standard geological, geochemical or geophysical prospecting methods. Layered and concentrically-zoned deposits are more prospective than Alpine-type deposits. Assuming that a favourable igneous body has been located, according to Page and others (1973), the following procedure should be adhered to: (1) close-spaced sampling and analysis of mineral phases and rocks for platinoids as well as associated elements such as Cu, Ni, Cr, Fe, Ti and V, and establishment of their correlation;

(2) define areas with high-correlation parameters, recalling that mineralized layers could be very thin but extremely persistent laterally. Considering that some of the platinoids are soluble or partly soluble in the weathering cycle, geochemical techniques may be applied directly to the stable PGM (Os, Ir, Ru, Rh) although the use of this technique has been extremely limited to date.

SOUTH AFRICA

Sources

Primary platinoid deposits occur in three ages of rock in South Africa: (1) Archaean - associated with nickel-copper sulphide deposits in greenstone belts; (2) Proterozoic - with nickel-copper sulphides in the Bushveld Complex, either as nickel pipes at the base of the Complex (probably derived deposits, see below), in the Vlakfontein area west of the Pilanesberg, or with three distinct chrome-bearing pegmatoidal stratiform layers (Merensky Reef, Pseudoreef and UG2 chromite) within the upper Critical zone; (3) Mesozoic - in thick differentiated post-Jurassic (post-Karoo) dolerite sheets, associated with typically magmatic iron-nickel-copper sulphides within the basal ultramafic differentiates.

Derived deposits consists of various pipe-like bodies in the Bushveld Complex although these are of limited economic potential. The more important of these are hortonolite-dunite replacements in the Critical Zone and anorthositic bodies in the upper Main or lower Upper Zones. Secondary deposits include the occurrence of osmiridium within the well-known Proterozoic conglomerate reefs of the Witwatersrand placer deposits, where the platinoids are recovered as a by-product to gold mining. Many unprofitable alluvial and eluvial deposits have derived a low platinoid content from the Bushveld Complex in the Lydenburg district.

The most important sources of the platinoids to date have been the Merensky Reef and the Witwatersrand. From 1939 to 1956 their respective contributions to PGM production were 95,38% and 4,62%.

Production

Unfortunately South Africa's production record is incomplete, since no local figures are available subsequent to 1956. From 1939-1956 the total production was 80 815,622 kilograms (2 598 289 oz.) and for five year periods as follows (figures in parenthesis refer respectively to Bushveld and Witwatersrand sources): 1941-1945, 17% (16,0%; 35,0%); 1946-1950, 20,5% (19,9%; 32,6%); 1951-1955, 62,5% (64,1%; 32,4%). The production growth from 1941-1955 (figures in parenthesis refer respectively to the Bushveld and Witwatersrand sources) was an average 14,60% (15,44%; 1,10%) per annum as follows: 1941-1945, +3,09% (+3,41%; +1,01%); 1946-1950, +12,66% (+13,80%; +0,70%) and 1951-1955, +28,06% (+29,12%; +1,60%). It is of interest to note that from 1939-1956, the price of Bushveld platinoids rose by 7,01% per annum as follows: 1941-1945, -0,44%; 1946-1950, +22,52% and 1951-1955, +0,41%. For the same period, the price of Witwatersrand platinoids rose by 11,25% per annum as follows: 1941-1945, -2,57%; 1946-1950, +22,52% and 1951-1955, -2,22%.

Foreign figures (U.S.A.) suggest that South African production for 1961-1975 was 567,979 kilograms (18 261 000 oz.) of platinoids as follows: 1961-1965, 12,7%; 1966-1970, 27,3% and 1971-1975, 60,0%. The average production growth rate was 19,31% per annum as follows: 1961-1965, +26,82%; 1966-1970, +16,40% and 1971-1975, +14,72%. The 1975 production was 83 979 kilograms (2 700 000 oz.).

Reserves, Resources

Estimates of reserves or resources depend largely upon the grade assumed for the various platinoid-bearing "reefs" in the Bushveld Complex, and of the ratios of the platinoids in those ores. Recent grade estimates are as follows: Merensky Reef (MR) *in situ*, 5,14 g/ton (Newman, 1973); MR *in situ* 8,8 g/ton (Vermaak, 1976, using data from Wagner, 1929); MR recovery grade 5,5 g/ton; UG2 chromitite layer 6,0 g/ton; Potgietersrus "platreef" (PR) recovery grade 3,0 g/ton (Von Gruenewaldt, 1976). The platinoid proportions in percent were supplied by Cousins and Vermaak (1976) as follows:

Reef	Pt.	Pd.	Ru.	Rh.	Ir.	Os.	Au.
Merensky	59	25	8	2	1	0,8	3,2
UG2 chromite	41	34	12	9	1,9	1,7	0,4
Platreef	42	46	4	3	0,8	0,6	3,4

Identified resources estimates were undertaken as follows (note that R.S.A. means South Africa; BC means the Bushveld Complex; WWR means the Witwatersrand reefs. Quoted in millions of kilograms of metal):

TRENDS, EVENTS, OUTLOOKS

Domestic

From 1966 to 1974, South Africa's share of world production for platinum rose from 43,5% to 68,8% and of palladium from 13,6% to 30,1%. South African production is expected to grow at the rate of 4% per annum so that by the year 2000, the production will be 124 414 kilograms (4 million oz.) of platinum and 43 345 kilograms (1,4 million oz.) of palladium giving a total production of 167 959 kilograms of those metals which based on the 1976 rand, should be worth R672 million.

World

Except for its use in jewellery, the world recession had a very drastic effect on the PGM market. Sales of the metals in 1975 to U.S. industries fell by 34% to about 1,3 million oz., and U.S. imports fell by 41% to 1,9 million ounces. Nevertheless, forecasts in the U.S. expect demand to increase by 3% per annum until 1980. World production rose by 1% in 1975, with the U.S.S.R. and Canada producing to make up for the 4,76% cutback of production in South Africa. The markets, during the beginning of 1976, were over-supplied with PGM caused mainly by cutbacks in industrial expansion. The gradual overseas recovery of business conditions are expected to normalise platinoid demands, but this cannot be expected before 1977 or later. There are many bullish indicators. With the use of platinum and palladium well established as catalytic exhaust converters in the U.S.A. and Japan, this will probably spread to other countries as emission standards become more stringent. There also seems little reason to doubt the continued demand for the metals in jewellery, especially in Japan, or of that use spreading to other countries. Research has developed the use of platinum in fuel cells and for the treatment of cancer with encouraging results, although much more research is needed. There is a developing interest in using platinum in coinage and medallion and for investment purposes.

SILVER

GENERAL

Commodity Type

Silver was one of the first metals known to man. Although a large variety of silver minerals are known (sulphide, antimonides, tellurides, bismutho-sulphides etc.) they are usually complexed with other metals notably lead, gold, arsenic and copper. There are very few mines which produce silver as a primary product so that it is produced as a co-product or by-product from ores of copper, lead, zinc, gold, manganese, cobalt, nickel and uranium. Silver can also substitute for other metals in base-metal sulphide deposits, notably silver-rich galena, sphalerite, chalcopyrite, gold and pyrite.

The proportion of silver in bullion, coin or jewellery is expressed by its fineness or parts per thousand. Fine silver is pure 100% silver or 1 000 fine. Sterling silver is 925 fine with 75 parts copper. Coin is 900 fine with the balance being copper. Bullion is 999 fine.

Utilization

Silver is a major industrial metal. It is exceptionally ductile and malleable and has the highest electrical and thermal conductivity of all metals. Its compounds are extremely photo-sensitive and it is stable in air and water but tarnishes rapidly when exposed to sulphurous compounds. U.S. uses during 1975 were in photography, 27%; silverware, 22%; electrical, 20%; brazing and solders, 8%; and other, including dental and medical products, catalysts, bearings, jewellery and coins, 23%. The free world is confronted with a long-range problem of a serious imbalance between the high consumption and low production of new silver.

Geology, Exploration

Two main types of deposits occur, those with co-product or by-product silver and those deposits with silver as the main constituent. Silver is an important by-product in porphyry copper deposits; copper-lead-zinc or lead-zinc replacement deposits or vein clusters; massive sulphide deposits; Mississippi Valley- and Alpine-type lead, zinc and fluorspar deposits; copper deposits in sandstones and shales; native copper deposits; gold deposits in veins, conglomerates or placers; and in nickel and magnetite deposits. Silver as a major constituent occurs within epithermal veins, lodes and pipes; epithermal disseminated and breccia deposits; epithermal silver-lead-zinc replacement deposits; epithermal silver-manganese deposits; epithermal silver-copper-barite deposits; mesothermal silver-lead-zinc-copper deposits; cobalt-silver, cobalt-uraninite-silver and cobalt-silver-zeolite deposits; in sandstone silver deposits; and in sea-floor muds or hot spring-deposits.

Reefs	Strike	Depth	Platinum	Palladium	Other	Total	Source
R.S.A.	-	-	-	-	-	6,2207	Ageton and Ryan, 1970
B.C.	-	-	-	-	-	20,4038	Page and Others, 1973
W.W.R.	-	-	-	-	-	0,0233	ditto
Total:	-	-	-	-	-	20,4271	ditto
M.R.	282 km	1 372 m	9,8909	3,9501	2,6438	16,4848	Newman, 1973
UG2	282 km	1 372 m	24,8205	9,9220	6,6250	41,3675	ditto
Total:	-	-	34,7114	13,8721	9,2688	57,8523	ditto
M.R.	230 km	1 200 m	10,7085	4,5375	2,9040	18,1500	Von Gruenewaldt, 1976
UG2	250 km	1 200 m	13,3250	11,0500	8,1250	32,5000	ditto
P.R.	30 km	1 200 m	5,1408	5,6304	1,4688	12,2400	ditto
Total:	-	-	29,1743	21,2179	12,4978	62,8900	ditto

The steadily increasing identified resources are probably a function of better data and certainly does not reflect new discoveries. Assuming a resources figure of 60 million kilograms (1 929,042 million ounces) of PGM, then at present South African production, the reserves will take some 714 years to deplete. Recent overseas figures (Commodity Data Summaries, 1976), place South African reserves at only 12,4414 million kilograms (400 million ounces) or about 70% of world reserves but these are probably grossly underestimated. If half the identified resources could be considered as reserves, then South Africa probably accounts for 85% of world reserves.

WORLD

U.S. Depletion Allowance

Domestic, 22%; foreign, 14%.

U.S. Prices

From 1961-1975 the price of platinum rose by 5,06% per annum and that of palladium by 11,13% per annum as follows (palladium in brackets): 1961-1965, +3,57% (+7,25%); 1966-1970, +6,36% (+3,37%); and 1971-1975, +5,25% (+22,76%). Sharp price drops were registered by both metals in 1976 as follows (Pd. in brackets): January 1975, \$164 (\$117); January 1976, \$147 (\$45); and March 1976, \$138 (\$37); prices being per ounce of metal.

U.S. Import Sources

From 1958-1974 the U.S. import sources were as follows (trends shown in brackets): U.K., 32,8% (27-47-30%); U.S.S.R., 26,6% (17-34%); Canada, 12,4% (22,0%); Switzerland, 6,4% (17-0%); R.S.A., 3,6% (0-19%); Netherlands, 1,1% (0-5-0%) and other, 17,1%. It should be noted that the U.K. obtains its platinoids from South Africa.

Production

From 1961-1975, world production rose by 14,52% per annum as follows: 1961-1965, +29,39%; 1966-1970, +7,37% and 1971-1975, +6,08%. Production for 1975 was 180 431 kilograms (5 801 million oz.), with the contribution by country as follows: R.S.A., 46,5%; U.S.S.R., 44,8%; Canada, 7,8%; other Market Economy Countries, 0,3%; U.S.A., 0,3% and Columbia, 0,3%.

Reserves, Resources

Doubt has been expressed above about the validity of South African resources (12,4414 million kilograms, 400 million oz.) as quoted in U.S. sources. Nevertheless, if those figures are used, the countries contributing to world reserves are as follows: R.S.A., 71,2%; U.S.S.R., 26,7%; Canada, 1,8%; U.S.A., 0,2%; Columbia, 0,1%. The total reserves are 17,4739 million kilograms (561,8 million oz.) which suggests that the reserves at 1975 production rate would last for about 97 years. World resources estimates vary between 34,2137 to 55,9861 million kilograms (1 100-1 800 million oz.) which are 2 to 3 times the estimated reserves and 5 to 9 times the estimated total consumption of primary metal during the 1975-2000 period.

Geological, geochemical and geophysical methods are used to find the ores in which silver is a by-product or a primary product. Silver minerals are notably difficult to identify by field or mineralogical methods, especially as they occur in microscopic-sized crusts, grains or inclusions. At the same time, silver-bearing galena, sphalerite, tetrahedrite and copper sulphides are no different from their silver-free counter-parts so that all ores should be chemically determined for silver, notably in those (sphalerite, pyrite, smithsonite, chalcocite, manganese) which are commonly overlooked. Silver could constitute a valuable product which may render low-grade ores viable.

SOUTH AFRICA

Sources

By-product silver from gold mining is the chief source of the metal in South Africa. It occurs in the Witwatersrand gold reefs at a ratio of one part silver to ten parts of gold. Silver also occurs in most lead and copper deposits in varying proportion throughout South Africa. Primary silver has been worked at Argent near Pretoria, at the Albert silver mine near Bronkhorstspruit and at the Willows silver mine east of Pretoria. Other deposits in the Pretoria Group, associated with diabase intrusions, have been worked. Some silver was recovered from the Maitland mine near Uitenhage in the Cape Province.

Production

South Africa's total production from 1940-1975 was 2 234 580 kilograms (71 843 415 oz.) as follows: 1941-1945, 9,40%; 1946-1950, 8,08%; 1951-1955, 8,69%; 1956-1960, 12,96%; 1961-1965, 18,88%; 1966-1970, 19,57%; and 1971-1975, 22,43%. The 1975 production was 95 923 kilograms. The average annual production growth was 10,76% as follows: 1941-1945, -0,38%; 1946-1950, -2,05%; 1951-1955, +5,88%; 1956-1960, +9,01%; 1961-1965, +7,16%; 1966-1970, +57,27%; 1971-1975, -1,53%.

Reserves, Resources

The reserves and resources position is as follows:

Reserve-Resource	Area	Kg. Silver	Source
Mineable reserves	1/10 of gold reserves	1 500 000	-
Demonstrated resources	Broken Hill deposit	4 151 000	Rand Daily Mail, 6.8.1975
	Black Mountain deposit	2 106 000	Coal, Gold, Base Min., 1974
	Prieska	376 000	Mining Mag., 1974
	Total:	6 633 000	
Inferred resources	Big Syn, Aggeneys	1 000 000	Mining Mag., 1975
	Grand Total:	9 133 000	

At the 1975 production level, these reserves will last for 95 years.

WORLD

U.S. Depletion Allowance

Domestic, 15%; foreign, 15%.

U.S. Prices

The price (average New York, c/oz.) rose by an average of 13,63% per annum from 1961-1975 as follows: 1961-1965, +7,50%; 1966-1970, +8,13%; and 1971-1975, +25,25%. The average 1975 price was 441,852 c/oz.

U.S. Import Sources

From 1958-1974 the import sources were as follows (figures in brackets indicate past trends):

Canada, 42,4% (27-60-35%); Peru, 17,9% (14-22-15%); Mexico, 15,7% (20-8-27%); R.S.A., 2,7% (0-12-0%); Honduras, 1,4% (0-6-0%); U.K., 0,6% (0-9%); and other, 19,3%.

Production

As stated before, silver is the one metal where new mine production has fallen very short (1975, 170 million oz.) of consumption since 1959. Production during the period 1961-1975, only rose by 1,59% as follows (the figures in brackets show the average deficit in millions of ounces, where available): 1961-1965, +2,02% (61,6); 1966-1970, +3,96% (105,95) and 1971-1975, -1,21%. The 1975 world production was 8,80 million kilograms of silver derived from the following countries: other Market Economy Countries, 29,8%; Central Economy Countries, 17,1%; Peru, 14,4%; Mexico, 13,7%; Canada, 13,1%; and U.S.A., 11,9%.

Reserves, Resources

World reserves of silver are 189,7312 million kilograms (6 100 million ounces) in the following countries: Central Economy Countries, 32,8%; U.S.A., 24,8%; Mexico, 14,0%; Canada, 11,6%; Peru, 10,0%; and other Market Economy Countries, 6,8%. Large resources are available and will become mineable at higher market prices, which includes low-grade base metal deposits.

TRENDS, EVENTS, OUTLOOKS

Domestic

With the discovery of new deposits with large identified and inferred silver resources, the waning production can be augmented considerably. With a serious shortage of new mined silver in the world, the outlook for the metal must be good and the favourable price should stimulate re-evaluation of current base metal deposits for their silver content and encourage new prospecting.

World

The U.S. expects the demand for silver to rise by about 2% per annum to 1980. The serious shortfall, 170 million ounces in the Market Economy Countries during 1975, will place increasing reliance on imports, secondary recovery and withdrawal from current stocks. Coin melting remains a large potential source of bullion silver. The moderately optimistic outlook for the general economy might stimulate greater consumption of silver in the immediate future.

TIN

GENERAL

Commodity Type

Cassiterite (SnO_2) contributes the bulk of tin to industry although small amounts are recovered from tin sulphide minerals (stannite, cylindrite, teallite). Other tin minerals (tellurides, selenides) are formed at high pressures and temperatures. Tin seldom occurs alone in minerals but is complexed with other cations (silver, copper, lead, iron, tantalum, calcium etc.). Tin metals have two modifications: "white" tin (tetragonal) and "grey" tin (cubic). At low temperature the heavy white tin crumbles to a powdery mass of grey tin. This change is prevented when tin is alloyed with other metals so that tin is seldom used in elemental form. Virgin tin is sold in bars, ingots, pigs and slabs in weight of 112 lbs. although pigs of tin imported into the U.S.A. weigh 100 lbs. Types include electrolytic tin (99,98% Sn), Grade A, high purity (99,8% Sn also called "Straits" from Malaya or "Longhorn, 3 star brand" from Texas), lower grade (97,7% Sn) and common copper- or lead-alloying tin (99% Sn).

Utilization

The most important property of tin is its extreme fluidity when molten and its ability to wet other metals and alloys, so that tin plating is its major use. The metal is non-toxic, easily melted and has a low friction coefficient and forms a thin layer of tin oxide on exposure, thus rendering it inert to weak acids, bases, air and other corrosive agents. In decreasing order of abundance, the most important uses are in tinplate, solders, bearing alloys, bronze, chemicals and coatings other than tinplate. Substitutes (plastics, aluminium, steel) are replacing tinplate but coating with tin is still done in newly developing nations. Research is finding new uses for tin, thus offsetting the capture of marketing by substitutes. One of the fastest growing new uses

is the production of organotin chemicals which are effective pesticides, fungicides, wood preservatives with low toxicity and as a stabilizing agent in polyvinyl chlorides (PVC). Tin-niobium alloys have found to be superconductors for use in space technology and may open new fields of trapping energy for cheap and unlimited electrical power. An important use is in low-fusion eutectic alloys (with bismuth and antimony) which are presently irreplaceable. The chief U.S. utilization of tin in 1975 was in tin cans and containers, 43%; electrical, 14%; transportation, 12%; construction, 11%; machinery, 9% and chemicals, 6%.

Geology, Exploration

Tin occurs in lode and placer deposits. Lode tin deposits are classified into six distinct types: (1) pegmatite deposits; (2) pneumatolitic-hydrothermal deposits; (3) subvolcanic or tin-silver deposits; (4) disseminated deposits; (5) contact-metamorphic deposits, and (6) fumerole deposits. Placer deposits are more productive and cheaply mined and supply most commercial tin. Placers are conveniently classed as residual, eluvial (slope), alluvial (stream), marine and fossil placers.

Tin lodes commonly occur in the apical portions of granitic masses, in fractures around them or in impervious sediments overlying them and such areas are of overriding importance in prospecting for tin. A very real problem is the extreme complexity of the geochemical tin environment and the ineffectiveness of distinguishing tin-bearing from barren granites by geochemical association of major or minor elements. Add to this the fact that there are very real problems of analysing for tin and it will be seen that most geochemical methods are not effective unless tin sulphide minerals are available (stream sediment sampling). The only alternative is the trustworthy method of examining panned concentrates from samples collected regionally. If known lodes carry abnormal amounts of associated base metals (Cu, Pb, Zn, W) then a geochemical survey may be successful in locating veins or lodes, as may the almost ubiquitous association of fluorine and boron with tin deposits.

SOUTH AFRICA

Sources

Tin occurrences may be subdivided into four different ages: Archaean deposits and early-, mid-, and late-Proterozoic deposits. In the Archaean, tin occurs very sporadically in pegmatites of the oldest granite-greenstone terrains. The main deposits occur in the early-Proterozoic granitic phase of the Bushveld Complex. They occur either as syngenetic pegmatite-pneumatolitic pipes and impregnations in the granite (Zaaiplaats, near Potgietersrus) or as epigenetic hydrothermal veins, in impervious-sedimentary traps, as impregnation deposits, as fault breccia and replacement deposits within quartzitic and arkosic sediments (Rooiberg-Leeuwpoort), in felsites, granophyres or granites. Mid-Proterozoic deposits are found in pegmatites of the granite-gneiss terrain enveloping the Bushmanland sequence of the north-western Cape. Pegmatites possibly related to the Richtersveld Complex are also tin-bearing. Tin occurs in pegmatites of similar terrains in Natal. The late-Proterozoic vein deposits are those associated with the Cape granites (Kuils River). The only tin mined at present comes from the Bushveld deposits.

Production

From 1941-1975, South Africa produced 80 890 tonnes of tin concentrate. From 1939-1956, the concentrate averaged 58,94% Sn and using this figure, the concentrate produced yielded 47 676 tonnes of metal. From 1953-1975, 18 309 tonnes of metallics were produced giving a total of approximately 65 985 tonnes of metal to date. In five year periods, the production of concentrate was as follows (metallics in brackets): 1941-1945, 4,7%; 1946-1950, 4,8%; 1951-1955, 11,6% (1953-1955, 15,9%); 1956-1960, 15,7% (17,2%); 1961-1965, 16,3% (25,6%); 1966-1970, 18,5% (19,5%); and 1971-1975, 28,4% (21,8%). Average annual production growth in concentrates was 5,79% and for metallics, 2,16% as follows (metallics in brackets): 1941-1945, -3,84%; 1946-1950, +7,49%; 1951-1955, +19,09% (1953-1955, +30,80%); 1956-1960, +1,37% (-13,43%); 1961-1965, +2,35% (+10,27%); 1966-1970, +3,93% (-8,17%) and 1971-1975, +10,13% (+5,36%). In 1975, the production was 5 652 tonnes of concentrate and 780 tonnes of metallics.

According to updated data from Lenthall (1974), total production from the Bushveld Complex up to 1971 had yielded 89 277 tonnes of metallic tin from about 134 400 tonnes of concentrate (66,42% Sn). Up to 1971 (Lenthall's study), the distribution of production of metallic tin was as follows: Rooiberg tinfield, 56,06%; Zaaiplaats tinfield, 31,56%; Nylstroom tinfield, 7,7%; Olifants tinfield, 0,17% and Moloto tinfield, 0,15%. The importance of the various host rocks can also be adjudged from his study of the yield of metallic tin: sediments, 56,16%; granites, 35,68%; felsites, 7,92% and granophyre, 0,24%.

Reserves, Resources

The nature of the producing tin occurrences is such that estimates of reserves and resources are virtually impossible to establish and consequently no figures are available.

WORLD

U.S. Depletion Allowance

Domestic, 2%; foreign, 14%.

U.S. Prices

From 1961-1975, tin prices rose by an average of 10,25% per annum as follows: 1961-1965, +12,57%; 1966-1970, -0,19%; and 1971-1975, +18,36%. The price in 1975 was 346c/lb. (New York) which showed a drop of 12,69% over the previous year.

U.S. Import Sources

From 1958-1974, the U.S. import sources were as follows (figures in brackets show trends): Malaya, 67,2% (53-83-54%); Thailand, 14,5% (0-27-19%); Indonesia, 3,4% (17-0%); Bolivia, 2,5% (sporadic); U.K., 2,0% (13-2-0%); Nigeria, 1,3% (5-3-0%); Congo, 0,5% (4-0%) and other, 8,6%.

Production

From 1961-1975 world tin production rose by an average of 0,92% per year as follows: 1961-1965, +1,17%; 1966-1970, +2,65% and 1971-1975, -1,07%. The 1975 production was 217 434 tonnes of metal. The contributing countries in the free world were as follows: Malaysia, 37,3%; Bolivia, 16,4%; Indonesia, 14,1%; Thailand, 9,5%; Australia, 5,3%; Nigeria, 2,8%; Zaire, 2,4%; Brazil, 2,3%; U.K., 1,9%; R.S.A., 1,6% and others, 6,4%. Contributing countries, including the communist countries, are as follows: Malaysia, 29,4%; U.S.S.R., 13,8%; Indonesia, 11,2%; Bolivia, 10,8%; Peoples Republic of China, 9,3%; Thailand, 8,2%; Australia, 4,7%; Nigeria, 2,3%; Zaire, 1,9% and others, 8,4%.

Reserves, Resources

In 1950 the world reserves stood at 5,0802 million tonnes of metal. A detailed survey in 1973 indicated the following (tonnes metal):

<u>Reserves:</u>	Measured and indicated	3 708 535	<u>Source:</u> Sainsburg and Reed, 1973.
	Inferred	6 429 342	
		10 137 877	
<u>Conditional Resources:</u>	Paramarginal	5 974 356	
	Submarginal	4 443 173	
		10 417 529	
<u>Undiscovered Reserves:</u>	Hypothetical	9 438 060	
	Speculative	7 625 128	
		17 063 188	

In 1975 the reserves stood at 10 363 680 tonnes of tin metal contributed by the following countries: Indonesia, 23,5%; Peoples Republic of China, 14,7%; Thailand, 11,8%; Bolivia, 9,8%; Malaysia, 8,1%; U.S.S.R., 6,1%; Australia, 3,2%; Nigeria, 2,7%; Zaire, 2,0%; U.S.A., 0,4% and other, 17,7%.

TRENDS, EVENTS, OUTLOOKS

Domestic

It has been estimated that unless significant new tin discoveries are located, South Africa's tin mining may have ceased by the year 2000. South Africa's consumption is expected to slow down, initially to 5% per annum and eventually to 2,5%, leading to consumption of 5 600 tonnes in the year 2000. In view of this, considerable prospecting activities are being undertaken in the Bushveld granite as a whole and in the Potgietersrus and Rooiberg areas in particular.

Foreign

The fortunes of the tin market were very much in line with those of other metals during 1975. The International Tin Council consequently directed its activities towards rectifying the imbalance between supply and demand by adjusting upwards its floor and ceiling prices and by introducing export control amounting to an 18% reduction from the 1974 production rate (this was later repealed). From January 1975 to June 1975, buffer stocks rose from 142 to 11 830 tonnes, ending the year with 20 071 tonnes. Although increasing fuel and mining costs caused closedown of many Malasian mines (122 in all), this was offset by increasing export from the People's Republic of China and Burma which depressed the market. Nevertheless the U.S. growth in demand is expected to be maintained at 1% per annum to 1980 (consumption 300 000 tonnes by the year 2000).

URANIUM

GENERAL

Commodity Type

In unoxidized black ores, uranium is tetravalent and occurs as the minerals uraninite and coffinite with a pyritic gangue. The multiple oxides, brannerite and davydite are the principle minerals in some ores. Tetravalent uranium substitutes for thorium and other elements in minerals such as monazite, uranothorite, multiple oxides of niobium and tantalum and for calcium in carbonate fluorapatite. It also occurs in coals and black marine shales. In oxidised ores, uranium is hexavalent forming oxide, vanadate, arsenate, silicate, sulphate and carbonate compounds which are hydrous and commonly bright yellow or green in colour. Uranium is a silvery metal with three semi-stable isotopes (U^{238} , U^{235} and U^{234} in the ratio 99,3%, about 0,7% and about 0,005% in nature). U^{235} is fissionable and U^{238} on bombardment becomes plutonium-239 is fissionable.

Utilization

Prior to 1942, uranium was used chiefly as a glass and ceramic glaze pigment, but after that date nuclear fission was demonstrated and it thus constitutes an important future energy source with pressure being applied to solid fuels by the escalating cost of liquid fuels. Thus with continued development of nuclear reactors to generate electricity, uranium is destined to become one of the principal energy sources of the world. Coproduct radio-isotopes of nuclear reactors have a very wide use. The other use of uranium is in strategic and military applications. About 94% of U.S. demand during 1975 was for nuclear fuels, the balance being used as depleted uranium stocks for ballast, counter weights and balances in aircraft, radiation shielding, alloys, catalysts, glass colourants and electrical components.

Geology, Exploration

The principal sources of workable uranium deposits are as follows: (1) peneconcordant masses in continental and marginal marine sandstones, in coaly rocks and in nonmarine limestones; (2) deposits in Precambrian quartz-pebble conglomerate placers; (3) vein deposits filling faults, joints and fracture zones; (4) epigenetic hydrothermal deposits in granite aureoles; (5) uraniferous igneous rocks, mostly pegmatites and alkaline rocks; (6) uranium-bearing phosphatic rocks; and (7) marine black shales rich in organic matter.

Radiation counters are the commonest tools for uranium prospecting. They are of two types; geiger counters (beta and gamma radiation) and scintillometers (gamma radiation) which are more sensitive and respond faster than geiger counters. Counters can distinguish uranium from thorium or radioactive potassium-40 radiation. Direct prospecting methods include airborne or ground-based radiometric surveys, drill-hole logging with counters, water analyses and soil or colluvium geochemical surveys. Indirect methods utilize the geochemical response of tracer elements and the geophysical (magnetic, resistivity and spontaneous potential) attributes of the enveloping rocks. Under development is an indirect technique using Eh and pH of waters to evaluate sandstone aquifers and delimit favourable areas for exploration.

SOUTH AFRICA

Sources

Uranium is produced in South Africa mainly as a byproduct of the gold mining industry. It occurs in the conglomerate reefs of the Dominion Reef - Witwatersrand - Ventersdorp supergroups and in the essentially basal member (Black Reef) of much of the Transvaal Supergroup. Although none of the torbanite and pitchblende-bearing pegmatites are considered a viable source of uranium at present,

they, together with the various alkaline and carbonatite complexes, could constitute important sources of uranium in the future. One of the major uranium discoveries in Southern Africa of late has been the Rössing deposit in South West Africa. There is also currently considerable interest in occurrences of uranium in fluvial channels in the Beaufort Group of the Karoo Supergroup in the Beaufort West-Sutherland area of the south-western Cape Province.

In 1967, the Atomic Energy Act allowed private ownership of uranium and the Nuclear Fuels Corporation of South Africa (Pty.) Limited (NUFCOR) was established as a private company, jointly owned by all the South African uranium-producing gold-mining companies and the seven principal mining finance groups. NUFCOR controls a central uranium processing plant and markets the joint uranium production, subject to certain controls exercised by the Atomic Energy Board relating to international safeguards, public safety and national interest. During 1975 the Atomic Energy Board announced that a new process of uranium enrichment had been developed in South Africa.

Production

The first uranium extraction plant started in 1952 and by 1957 there were 17 plants in operation. The total output to date has been 84 989 882 kilograms of U_3O_8 from a total of 314 163 000 tonnes of ore showing an average grade of 0,271 kilograms of U_3O_8 per tonne treated (271 p.p.m.). The production occurred as follows: 1952-1955, 5,9%; 1956-1960, 31,2%; 1961-1965, 23,9%; 1966-1970, 19,7%; and 1971-1975, 19,3%. Ignoring the rapid growth in production during the early years (1952-1955) the average growth rate has only been 0,80% per annum as follows: 1956-1960, +14,98%; 1961-1965, -13,66%; 1966-1970, +7,26% and 1971-1975, -5,36%. During 1975, the production was 2 809 490 kilograms U_3O_8 , down 8,62% from the previous year and continuing a downward trend since 1971.

Reserves, Resources

The South African reserves are stated to be 238 600 tonnes of U_3O_8 (von Backström 1973) as reasonable assured reserves recoverable at up to R19,07 per kilogram (\$10/lb., R1 = \$1,1558). Total resources of U_3O_8 are 351 443 tonnes. At the 1975 rate of production, the reserves should last for about 85 years.

WORLD

U.S. Depletion Allowance

Domestic, 22%; foreign, 22%.

U.S. Prices

An average rise of 10,34% per annum was registered in U.S. uranium prices from 1961-1975 as follows: 1961-1965, constant; 1966-1970, -3,84%; and 1971-1975, +34,85%. Uranium prices more than doubled to \$22/lb. U_3O_8 in 1975 over the price of the previous year.

U.S. Import Sources

From 1958-1974 the U.S. imports averaged as follows (trends in parenthesis): R.S.A., 47,8% (21-79-15%); Canada, 44,9% (70-17-83%) and others, 7,3%.

Production

World production showed a negative average growth of 3,10% from 1961-1975 as follows: 1961-1965, -13,46%; 1966-1970, +3,09% and 1971-1975, +1,06%. The total production of U_3O_8 during 1975 was 22 362 tonnes to which the following countries contributed: U.S.A., 47,1%; Canada, 20,3%; R.S.A. (including S.W.A.), 14,6%; France, 7,7%; Niger, 4,9%; Gabon, 3,6% and other Market Economy Countries and Australia, 1,8%. It should be noted that production figures for Central Economy Countries and Australia were not available.

Reserves, Resources

Total identified resources in 1973 were reported to be 1 456 830 tonnes of U_3O_8 from countries that had reported resources at that time. Reserves in 1975 stood at 1 179 340 tonnes to which the following countries contributed: U.S.A., 24,4%; Australia, 21,7%; R.S.A. (including S.W.A.), 20,2%; Canada, 18,5%; Niger, 4,0%; France, 3,7%; Gabon, 2,0% and other Market Economy Countries, 5,4%. It should be noted that no data was available for the Central Economy Countries. The reserves are based on R19,07/kg. value (\$10/lb.).

TRENDS, EVENTS, OUTLOOKS

Domestic

In keeping with the change in energy consumption trends since October 1973, South Africa, like most other nations, have been carefully scrutinising alternative energy sources with a view to reducing oil dependence. Consequently, not only active field exploration (77 000 metres of drilling in South Africa and S.W.A. during 1974, compared with 115 000 metres in 1975) but also research and development has been taking place to establish reserves and resources with confidence, to convert resources to reserves and also to expand existing resources. With rising prices of all energy-based commodities, the high capitalization of nuclear plants has been overcome to a large extent when it is considered that nuclear-generated electricity will be cheap in the long run. In addition, the development of a unique uranium-enrichment process has been developed by the Atomic Energy Board which must have materially assisted in the establishment of the Koeberg power station north of Cape Town as announced during 1976. The Koeberg station with a capacity of 900-1 000 MWe will be operational in September 1982 and a further plant will be operational a year later. The cost of the Koeberg plant will be R850 million and could use some 2 300 tonnes of U_3O_8 per annum.

Foreign

In spite of the realization that nuclear power is a long term necessity, the recession caused many countries with declared nuclear programmes to revise downwards their projections for nuclear power growth. But although reactor sales were down, the uranium supply industry was almost the only one that experienced strong demands and sharp price rises (\$US15 to \$US35 per lb. for immediate delivery) during 1975. Long-term delivery prices (1980) also increased from \$US25,35 to \$US47,45 (in constant money terms). The projection remains that there will be a shortfall in supply over demand during the end of the 1970's to the mid-1980's. World demand for uranium in 1975 was 27 000 tonnes U_3O_8 increasing to 115 000 tonnes in 1985 and 315 000 tonnes in the year 2000. These represent annual growths of 15,5% (1975-1985) and 6,9% (1985-2000). The cumulative demand up to the year 2000 will be 4 million tonnes U_3O_8 .

It is clear that with the establishment of the safety of nuclear generation plants (Rasmussen report in U.S., and others) the anti-nuclear lobby is losing ground. Coupled to this are the imperative economic considerations such as the rapidly rising cost of fuel oils, the long term cheapness and money saving of nuclear power (U.K. sources estimate savings of R85 million compared with coal and oil-fired power generation) and the release of the more versatile fuels for feed stock to other (petrochemical) industries. During 1975, it has been shown that U.S. nuclear power allowed 115 million barrels of oil or 25 million tonnes of coal to be put to other uses.

With the prices of U_3O_8 having made substantial gains throughout 1975-76, the outlook for uranium must be bright. Furthermore, the projected power capacity requirement of 2 million MW for the world by the year 2000, dictate that the requirements for uranium as a power generator will rise as follows: 1975, 18 000 tonnes; 1985, 82 000 tonnes; 1990, 130 000 tonnes; 1995, 180 000 tonnes and 2000, 236 000 tonnes or a 13-fold increase over the next 25 years at a compounded growth rate of 11% per year. Thus for at least the medium-term future, there is simply no alternative to the use of nuclear power in view of the relentless energy demands of world industry. At the same time it should be realised that doubling the price of uranium would only cause a 5% increase in the unit cost of electricity produced by water reactors; this to be compared with a 60% unit cost increase of electricity caused by doubling the price of fossil fuels. Thus a reassessment of world uranium resources is imperative and the demand for the metal appears assured.

VANADIUM

GENERAL

Commodity Type

Most of the 50 accepted vanadium minerals are only rarely found in nature. The most important ores contain either primary or secondary minerals. Primary minerals include coulsonite (iron-vanadium oxide); montroseite (hydroxyl-bearing iron-vanadium oxide); patronite (vanadium sulphide found in asphalt vein deposits); and roscoelite (potassium, vanadium, aluminium, hydroxyl-bearing silicate in sandstone deposits and gold-quartz veins). Secondary minerals include carnotite (hydrated potassium-uranium vanadate); the descloisite - mottramite series (hydroxyl-bearing lead-zinc to lead-copper vanadate) and vanadinite (lead vanadium chloride), all of which occur in the oxidized portions of near-surface base-metal deposits.

Vanadium is a bright silver-white to steel-grey metal of high specific gravity (5,87 at 15°C) and melting point (1 900°C). Technical-grade vanadium pentoxide is the common commercial product and is the feedstock for the production of ferrovanadium, other vanadium alloys and metal vanadium. Grades of ferrovanadium include: openhearth grade (50-57% V, -8% silica, 1-3% C), crucible

or special grades (either 50-57% or 70-80% V, 2,25% silica, 0,5% C) and refined, primos or high-speed grades (either 50-57% or 70-80% V, 0,5% or 1,5% silica, 0,2% C) and foundary grade (either 38-42% V or 50-55% V, 7-11% silica, 1% or 3% C). The metal is marketed either as 90% alloying grade or 99,5% high-purity ductile-metal grade. The oxide is available as fused black oxide (86-99% V_2O_5) also called black flake or black oxide, or air-dried oxide (83-86% V_2O_5). Chemical grades of vanadium pentoxide are high purity (99,5% - 99,94%) types. Ammonium metavanadate, sodium metavanadate, sodium orthovanadate and sodium polyvanadate (red cake) are feedstocks to the chemical industries.

Utilization

About 80% of vanadium is used to toughen and strengthen alloy steel and to control its grain size. Vanadium-bearing tool steels contain some 0,5-4% vanadium, commonly used with chromium, niobium, nickel and tungsten combinations in such steels. Such low-alloy steels are used for high-pressure pipelines and construction purposes (aircraft, atomic energy equipment, bridges and towers, farm machinery, tanks and pressure vessels, trucks and heavy mobile equipment). A small amount of vanadium is used, along with other metals, in case irons made for special purposes. Vanadium is also an alloying agent in nonferrous metals used chiefly with titanium in aerospace applications. Vanadium compounds have various uses in the chemical industry especially as catalysts in oil processing and in the manufacture of sulphuric acid, but also has uses as accelerators in rubber manufacture, in dyeing in colouring glass and ceramics, in driers for paint and varnish and in printing-ink manufacture. Vanadium metal with other alloys may be used as fuel-cladding material for advanced liquid- or metal-cooled fast-breeder reactors. In 1975 the major end uses of vanadium in the U.S.A. were transportation, 29%; machinery, 28%; construction, 20%; chemicals, 7% and other, 16%.

Geology, Exploration

Vanadium deposits are of two main types: syngenetic deposits of magmatic origin and epigenetic deposits. Syngenetic deposits include: (1) titaniferous magnetite deposits in layered or complex intrusive bodies; (2) non-titaniferous magnetite deposits containing more phosphorous but little titanium compared with the titaniferous variety; and (3) vanadium-bearing hydrothermal vein deposits associated with titanium or uranium mineralization. Epigenetic mineralization includes: (1) vanadate deposits (descloisite-mottramite series) as crusts and cavity fillings in oxidised lead or copper-zinc ores in arid regions; (2) deposits in sandstone together with uranium and copper ores; (3) asphaltite deposits; and (4) deposits associated with alkaline igneous complexes.

Because of the high background content of vanadium in many rock types and also because the metal is not readily soluble, standard geochemical methods of soil and stream sampling are not very successful in searching for vanadium deposits. The main tool of vanadium prospecting thus revolves around a knowledge of its geological associations as outlined above. Thus all deposits of the type outlined should be subjected to vanadium analysis. Search methods are naturally standard for those types of deposits.

SOUTH AFRICA

Sources

The largest source of vanadium in South Africa occurs within up to 22 titaniferous magnetic seams contained in the Upper Zone of the Bushveld Complex. They contain from 2,0% V_2O_5 in the lower seams, to 0,3% V_2O_5 in the upper seams. The only seam exploited presently in the eastern Transvaal by the current producers (Highveld Steel and Vanadium Corporation, a subsidiary of the Anglo American Group, and Transvaal Alloys, a subsidiary of the Otavi Mining Group) is the 1,8 metre thick main magnetite seam which averages about 1,6% V_2O_5 . The main seam in the Potgietersrus area is very similar, but in the western Transvaal, two distinct layers separated by 100 metres of troctolite, constitute the main seam; the lower layer contains about 1,8% V_2O_5 and the upper one about 1,55% V_2O_5 . In addition, a 2,5 metre thick felspathic magnetite layer occurring some 3 metres above the lower seam, averages 1,44% V_2O_5 . UCAR Minerals Corporation (Union Carbide S.A., Limited) are exploiting these seams for their vanadium content in the western Transvaal. Vanadium also occurs in the Bushveld chromite seam (0,05-0,81%, average about 0,2% V_2O_5).

Vanadium also occurs in manganese wad layers, associated with lead-zinc deposits, in the dolomites of the Zeerust area of the western Transvaal, and in quartz veins in the same district. Vanadium is a prescribed material under the Atomic Energy Act.

Production

South Africa produced 97 062 tonnes of "vanadium" from 1957-1975 as follows: 1957-1960, 2,2%; 1961-1965, 11,7%; 1966-1970, 18,8%; and 1971-1975, 67,3%. The "vanadium" production in 1975 was 19 002 tonnes. It must be stressed that "vanadium", in the production sense, includes a meta and polyvanadate, fused vanadium pentoxide, ferro-vanadium and carvan, the actual V_2O_5 content of which was 78,77%. Thus the actual V_2O_5 production was 14 968 tonnes. Production growth, excluding the

early years when production started, nevertheless escalated at 30,3% per annum as follows: 1961-1965, +24,99%; 1966-1970, +13,78%; and 1971-1975, +52,12%.

Reserves, Resources

Various resources estimates have been done for the main magnetite seam during the last few years as follows: (N.A. = not available).

Million Tonnes Ore	Strike	Thickness	Depth	V ₂ O ₅ Content, Tonnes	Remarks, Sources
192,3231	N.A.	N.A.	N.A.	3 238 795	Nel and Luyt, 1964 Fischer, 1973
2000,0000	N.A.	N.A.	N.A.	17 000 000	Fischer, 1975
401,0000	195 km	280 cm	30 m	6 731 000	Western Bushveld
295,5000	110 km	180 cm	30 m	4 728 000	Eastern Bushveld
159,0000	120 km	180 cm	30 m	2 544 000	Potgietersrus Bushveld
855,5000 (Total)	425 km	227 cm	30 m	14 003 000	Von Gruenewaldt, 1976

If the 1975 production is assumed to be tonnes based on V₂O₅ content, then the resources (based on the last figure) could last for 713 years. The total resources position in South Africa, which can only be based on a greater depth of exploitation, must be enormous.

WORLD

U.S. Depletion Allowance

Domestic, 22%; foreign, 14%.

U.S. Prices

From 1961-1975, U.S. prices rose by an average 8,21% per annum as follows: 1961-1965, -0,20%; 1966-1970, +17,08%; and 1971-1975, +7,76%. In 1975, the average U.S. price per lb. of V₂O₅ was \$2,76, up 30,19% from the previous year. In London, the price of Highveld fused 98% V₂O₅ was quoted at R1,427 (per pound, c.i.f.) at the start of 1975 and at \$2,16/lb. (R1,86/lb.) at the end of that year.

U.S. Import Sources

From 1969, the average import sources quoted are as follows: South Africa, 56,7%; Chile, 34,3%; U.S.S.R., 5,7%, and other, 3,3%. Previous to 1969, Canada, the Netherlands Antilles, Norway, the Netherlands and West Germany had supplied the U.S. needs.

Production

Actual world production figures for 1975 are not available as the U.S. production was withheld to avoid disclosing individual company confidential data. Prior to 1974, only the free world production has been quoted, in which production rose by 6,49% per annum as follows: 1962-1965, +2,61%; 1966-1970, +14,25%; and 1971-1974, +2,60%. In 1975, estimated free world production was 80,88% of the total world production of 20 411 tonnes V₂O₅, to which the following countries contributed: South Africa, 41,2%; U.S.A., 21,6%; U.S.S.R., 19,1%; other Market Economy Countries, 15,1%; and Chile, 3,0%.

Reserves, Resources

In 1970 world reserves of vanadium metal were estimated as 9 473 051 tonnes (16 910 154 tonnes V₂O₅) which had risen by 1975 to 19 395 612 tonnes (34 622 719 tonnes V₂O₅). An estimate of South African reserves by the U.S. Bureau of Mines in 1975 amounted to 1 814 369 tonnes of contained vanadium or 3 248 795 of V₂O₅ which is about 23,9% of South African resources. On that basis, the world reserves of vanadium are made up as follows: U.S.S.R., 74,8%; South Africa, 18,7%; other Market Economy Countries, 2,6%; Chile and Australia each 1,4%; and U.S.A., 1,1%. South Africa thus contains some 74,3% of free world vanadium reserves.

The resources of vanadium in the world are thought to be large, especially in carbonaceous shale and in vanadium-bearing titaniferous and non-titaniferous magnetite deposits. Vanadium might also in the future be recovered from other iron ores, phosphate rock, petroliferous deposits and other byproduct sources. Most of the world's vanadium is contained as a byproduct resource within other ores.

TRENDS, EVENTS, OUTLOOKS

Domestic

Local production of V₂O₅ is expected to double by 1980 from the 1975 production (14 968 tonnes to 29 937 tonnes or 6,7% growth rate per annum) after which the growth rate is expected to escalate at 4% (possibly at 6%) per annum, at which rate the output in the year 2000 should be 65 771 tonnes of V₂O₅. This, in terms of the 1976 constant rand, should be worth R230 million.

Foreign

The U.S.A. remains chief user of vanadium and she imported about 40% of her needs in 1975. The stockpile contained about 490 tonnes of vanadium pentoxide in 1975, all of which was classified as excess. None of this material was available for disposal and there were no sales during 1975. The U.S. demand for vanadium is expected to increase at a rate of 5% per annum and that of the Western World at a rate of 7,5% per annum until 1980. From 1959-1974, U.S. consumption growth was 8,2% per annum.

In spite of the decline in world steel production and a sharp fall in vanadium consumption during 1975, the market for vanadium remained reasonably firm. A lower demand was reported during the first quarter of 1976. Compared with other commodities utilized in the steel industry, the demand for vanadium has held up reasonably well despite rising production. The metal appears to be well placed and should benefit from the resumption of economic expansion. New producers expected to come on stream soon are the Finnish deposits at Mustavaara, western Australian deposits at Wundowie, Barrambie and Julia Creek in north-west Queensland, and a ferro-vanadium plant in Orissa State in India.

VERMICULITE

GENERAL

Commodity Type

Vermiculite is the name of a specific mineral but is also generally applied commercially to a group of micaceous minerals which expand as much as 20 times on rapid heating. The name is also used for the exfoliated product. The nineteen varieties of vermiculite that have been identified are all hydrous magnesium-aluminium silicates containing iron and other elements which have the characteristic lamellar micaceous structure and basal cleavage. Although authorities differ, X-ray studies indicate diffraction patterns for vermiculites differing from those of true micas. Only the vermiculite and jefferisite varieties have been mined commercially and their colour varies in the crude state from light brownish-yellow to yellowish-brown, to greenish, to almost black but almost always with a bronze cast. When heated, the colour changes to a gold, golden brown or bronze-metallic lustre. Chemical composition is of little value in gauging expandability of vermiculite and exfoliation tests, even by heating in an open flame in the field, provide the only satisfactory evaluation test.

Utilization

Exfoliated vermiculite is used chiefly either in concrete, plaster and cement aggregates, or as insulating material. Other uses include agricultural employment in horticulture, soil conditioning, fertilizer carriers or litter. In concrete aggregate, a minus 5- to plus 20-mesh exfoliated product is used to replace sand, gravel or crushed stone. Although this produces a light aggregate with low thermal conductivity (cement:vermiculite:sand = 1:3:2), its compressive strength is inferior to that of normal concrete. The finer exfoliate sizes are used in sound- or heat-insulated or fireproof plaster and ceilings. Vermiculite has thus contributed materially to light-weight building construction. As a fill insulator (refrigerators, cold-storage room, fireless cookers, thermal jugs, ovens, safes and water heaters), exfoliated vermiculite is sized from minus 3 mesh to plus 14 mesh, weighing about 71 to 92½ kilograms per cubic metre (2-2½ kilograms per cubic ft.). Very fine vermiculite, -100 mesh, is used in grease lubricants, fillers in plastic, type and rubber goods, wall-paper printing, paints, anti-cake agent in fertilizers, for increasing viscosity of oils, extender for gold and bronze printing inks and as carriers for agricultural chemicals,

insecticides, herbicides and fungicides. The chief U.S. uses of the crude exfoliated product in 1975 were: light weight concrete aggregate, 35%; insulation, 29%; plaster and cement aggregate, 17%; agriculture, 17% and miscellaneous, 2%.

Geology, Exploration

Vermiculite is associated with basic igneous rocks such as pyroxenite, peridotite, dunite and serpentinite, commonly where these are intruded by acid dykes or pegmatites. The vermiculite is thought to originate by hydrothermal action on the ultrabasic host rocks or by alteration of micaceous minerals (phlogopite, biotite, chlorite), with weathering playing an important role in the alteration cycle. Apart from the micaceous minerals, commonly associated minerals include quartz, feldspar, apatite, kyanite, corundum, asbestos, talc and clay minerals.

Since all ultrabasic rocks could be potential carriers of vermiculite, the standard methods of search can be applied to such bodies and any development of micaceous minerals in such rocks should be tested on an open flame for expansion exfoliation.

SOUTH AFRICA

Sources

The deposit associated with the Palabora Igneous Complex near Phalaborwa in the north-eastern Transvaal, is a vermiculite-pyroxenite-apatite pegmatoid. The vermiculite is derived from a phlogopite-bearing rock, into which it passes laterally, both vertically and horizontally. Black (iron-rich hydrobiotite) and golden-yellow (after phlogopite) varieties of vermiculite occur with the phlogopite, the latter type having the better expansion coefficient. Promising deposits are reported to occur within the Archaean schists of the Sutherland Range in the Letaba district of the north-eastern Transvaal and small deposits occur within the corundum-fields in the northern Transvaal. The Letaba deposits have not been mined and the other deposits are uneconomic.

Production

Production of vermiculite apparently started in 1953 and, since that date, 2 234 173 tonnes of the commodity has been produced as follows: 1953-1955, 5,5%; 1956-1960, 12,1%; 1961-1965, 20,1%; 1966-1970, 25,3% and 1971-1975, 37,0%. The production growth rate averaged 7,69% per annum over the years 1956 to 1975 as follows: 1956-1960, +4,75%; 1961-1965, +13,10%; 1966-1970, +1,62% and 1971-1975, +11,30%. The production during 1975 was 207 529 tonnes, up 13,64% on the previous year.

Reserves, Resources

The deposits being worked at Loolekop near Phalaborwa are estimated to contain several tens of millions of tons as demonstrated resources. The reserves of the so-called northern pyroxenite and pegmatoid, prospected by the Government, are conservatively estimated to be 5 216 313 tonnes to 7,3 metres depth and that of the area prospected by the Transvaal Ore Company Limited as between 55 and 74 million tonnes (25% and 30% recovery respectively) to 21,33 metres depth, giving a total of at least about 80 million tonnes of recoverable vermiculite (Hanekom and others, 1965). No estimates of reserves or resources were made of the Loolekop pegmatoid or the southern pegmatoid deposits, so that the demonstrated resources are probably somewhat of a minimum figure. At the 1975 production rate, these resources should last for 385 years.

WORLD

U.S. Depletion Allowance

Domestic, 14%; foreign, 14%.

U.S. Prices

Prices rose by 7,25% per annum from 1961-1975 as follows: 1961-1965, +2,89%; 1966-1970, +5,00% and 1971-1975, +13,87%. The 1975 price was estimated to be an average of \$42,00/short ton, f.o.b. U.S. mines, an increase of 41,51% over the previous year.

U.S. Import Sources

From 1959-1975, all the vermiculite imported by the U.S.A. originated from the Republic of South Africa.

Production

Production increased by 4,95% per annum on an average during the years 1961-1975 as follows: 1961-1965, +6,55%; 1966-1970, +2,83% and 1971-1975, +5,48%. The production in 1975 was 509 838 tonnes in the free world, to which the following countries contributed: U.S.A., 60,5%; R.S.A., 37,4%; and other Market Economy Countries, 2,1%.

Reserves, Resources

In 1975, the first estimate of the free world reserves (communist world not available) was undertaken. The reserves were estimated at 172 365 000 tonnes to which the following countries contributed: U.S.A., 52,6%; South Africa, 39,5%; and other Market Economy Countries, 7,9%. For this reserve estimate the South African reserves were given as about 68 million tonnes. Reserves and resources outside those of the U.S.A. and South Africa have been found to have inferior exfoliation characteristics.

TRENDS, EVENTS, OUTLOOKS

Domestic

From 1970-1975, 94,6% of South Africa's vermiculite production was exported and the rest was sold locally. Since vermiculite is used extensively in construction, the local and overseas slump in major construction would have adversely affected vermiculite consumption over the last few years. Should there be an upturn in the local and overseas economics, the demand for the commodity should improve.

World

U.S. demand for vermiculite is expected to increase at a rate of 4% per annum until 1980. A substantial increase in the use of finer-grained material (below 2 mm) will promote the exploitation of lower-grade deposits, while increased furnace exfoliation efficiency with a shorter dwell time, has improved the overall product. The fines, which were formerly discarded, can also be used increasingly in fire-proof cements and plaster and in agriculture as indicated above under utilization. With an improving economic situation, the future of vermiculite seems assured.

ZINC

GENERAL

Commodity Type

Some 55 species of zinc minerals are known and many contain zinc as a major component. The mineral most commonly exploited as the isometric sulphide mineral sphalerite or zinc blende which is a multi-coloured mineral although a resinous brown to yellow colouration occurs in the most common type. A dark brown to black variety of sphalerite, containing more than 10% iron, is called marmatite and a rare hexagonal variety is known as wurzite. A banded ore consisting of layered sphalerite and wurzite is known as schalenblende. The sulphides oxidize readily to form secondary minerals such as the carbonate, smithsonite and the hydrous basic silicate, hemimorphite. Other localised minerals include franklinite (iron-manganese-zinc oxide), willemite (zinc silicate) and zincite (zinc oxide). Zinc ores commonly contain economically significant amounts of lead, copper, silver and gold while associated trace elements include silver, cadmium, germanium, gallium, indium and thallium.

Elemental zinc is a bluish-white metal of high density (S.G. = 7,13) and relatively low melting (419°C) and boiling (906°C) points. It alloys well with other metals and, on exposure to air, it develops a thin impervious protective grey oxide film, an important characteristic in its use. Refined zinc is cast into slabs typically weighing 55 pounds, each of which is identified as to grade and producer by registered brand name cast into the metal. The slabs are strapped and loaded as pellets of about a short or long ton weight designed for fork-lift handling. Primary zinc is referred to as electrolytic or distilled zinc according to the reduction process used. Zinc dust is sold commercially according to strict size-grading with lead and iron impurities. Zinc oxide also has high purity with limitations on sulphur, moisture and volatiles.

Utilization

Zinc is used principally in the metallic form but also in the oxide form in the automobile, household-appliance and hardware industries. Slab zinc, the metallic form of the commercial metal,

is produced from the smelter in a variety of sizes, shapes and grades (98%-99,99% Zn) depending on impurities (lead, iron and cadmium with trace quantities of copper, tin or aluminium often present). The metal has three major uses: (1) in zinc-based alloy die castings; (2) in the galvanising of iron and steel products; and (3) in the manufacture of the copper-zinc alloy, brass. Another important outlet of the metal is in rolled zinc sheets while minor uses are in wet battery manufacture, in desilvering lead and in light-metal alloys. Much of the available zinc ores and a large portion of the metal produced are converted to zinc oxide and leaded zinc oxide. The former product is used extensively in the rubber, paint, ceramic and chemical manufacturing industries and in agriculture, photocopying and floor covering. Leaded zinc oxide is used as a pigment in paints and in the rubber industries. In 1975, the U.S.A. commercial consumption of end-product zinc was in construction materials, 35%; transportation equipment, 29%; machinery and chemicals, 13%; electrical equipment, 11%; and other uses, 12%. Possible substitutes for zinc in die casting are magnesium and aluminium, particularly if weight limitations are important. Aluminium sheeting substitutes for galvanised iron sheeting, as does plastic-coated sheeting, although there appears no satisfactory alternative to the large-tonnage utilization of zinc as a corrosive protector.

Geology, Exploration

Zinc generally occurs associated with lead in diverse geological environments in which a distinct deposit type can pass into another with no clear boundary. The following broad classification of deposit types is possible: (1) contact-metamorphic deposits; (2) irregular replacement deposits and associated fissure fillings; (3) vein deposits; (4) stratabound deposits in metamorphic rocks; (5) stratabound deposits in carbonate rocks (Mississippi Valley- or Alpine-type deposits); (6) stratiform deposits; (7) vulcanogene deposits, and (8) deposits formed by supergene enrichment or laterisation. Deposits in which zinc, lead, copper and silver occur together are classed according to the dominant mineral, or simply as base metal deposits where two or more metals are equally important.

Four main search techniques are applied: geological, geochemical, geophysical and direct physical. Geological mapping is important for plotting structure or alteration haloes and for finding extensions to orebodies using the parameter characteristics of the known orebodies. Geochemistry has wide application in soil and stream-sediment geochemistry although the extreme mobility of zinc is a problem in most geochemical surveys. Geophysical techniques depend on the physical properties (magnetic, electrical, gravity) of the orebodies compared to the surrounding rocks. Most zinc minerals do not contrast strongly with their environment so that these methods often rely on properties of the associated rock types. Although discussed separately, all the methods listed are best used in combination, with geology being of fundamental importance. Ultimately the discovery is best prospected by direct physical means such as pitting, trenching and drilling of favourable targets chosen by the other methods.

SOUTH AFRICA

Sources

Prior to the recent significant discoveries at Prieska, Gams, Aggeneys, Areachap and Platveld in the north-western Cape, South Africa's sources of zinc were very limited and were usually associated with lead, tin and copper mineralization. No good documentation of the geology of the recent major discoveries is available. The minor occurrences are with galena veins in the Argent district; as a pipe-like orebody of cadmium-bearing sphalerite, chalcopyrite and pyrite in a carbonate-siderite gangue within felspathic sericitic quartzites near Groblersdal; with tin- and copper-bearing pipes in the Potgietersrus tinfields; with copper in porphyries of the "copper-zinc line" of the Murchison Range; and with the lead-bearing ores in the dolomite of the Marico-Zeerust districts of the western Transvaal. A minor occurrence is at the Dania Mine, east of Nondweni in the Nqutu district of Natal.

Production

From 1953-1970 the production of zinc was sporadic and only 3 088 tonnes were produced but it is not clear whether this refers to ore concentrates or metal. After 1970, the Prieska Copper Mines (Pty.) Limited showed a rapidly increasing production, escalating at an average of 527,47% per annum to produce a total of 233 980 tonnes of concentrate. The concentrate production during 1975 was 127 624 tonnes, showing a 87,70% increase over 1974. The amount of zinc in the concentrate is stated to be 54% (Financial Mail, 5.10.73) which suggests a zinc metal production of 68 917 tonnes during 1975, of which 66 706 tonnes was exported (96,8%) at R139,16 per tonne.

Reserves, Resources

The South African resources of zinc metal have been estimated as follows:

Area	Resource Type	Zinc Metal, Tonnes
Prieska deposit	Demonstrated resource	1 819 000
Gams deposit	Demonstrated resource	6 882 000
Broken Hill, Aggeneys	Demonstrated resource	1 660 000
Black Mountain, Zuurwater	Demonstrated resource	438 000
Areachap	Demonstrated resource	68 947
Platveld	Demonstrated resource	65 318
Total:	Demonstrated resource	10 933 265
Big Syn deposit, Aggeneys	Inferred resources	1 700 000
Grand Total:		12 633 265

(Sources: Rand Daily Mail, 13 April 1971 and 6 August 1975; Coal, Gold and Base Minerals, April 1974; Van Rensburg and Beukes, 1974; Krüger, 1966) Although it is probably not valid, the resources could last for 183 years on the basis of 1975 production (based on production from one mine).

WORLD

U.S. Depletion Allowance

Domestic, 22%; foreign, 14%.

U.S. Prices

Average weighted prices for all grades of ore in the U.S.A. escalated at an average rate of 8,96% per annum during 1961-1975 as follows: 1961-1965, +2,95%; 1966-1970, +1,06%; and 1971-1975, +22,87%. The 1975 prices was 39,1 US cents per lb., up 8,91% from the previous year although the largest rise of +73,43% was registered from 1973-1974.

U.S. Import Sources

The sources of U.S. imported metal are as follows (trends in parenthesis): Canada, 47,0% (37-50-53%); Mexico, 15,8% (32-18-0%); Peru, 11,1% (16-6-0%); Australia, 3,3% (0-10-8%); Japan, 2,9% (0-11-17%); Belgium-Luxembourg, 0,4% (0-6%); and other, 19,5%. Ore and concentrate imports in 1975 originated from Canada, 61%; Mexico, 20%; Peru, 6%; and other, 13%.

Production

World production escalated at an average rate of 4,05% per annum from 1961-1975 as follows: 1961-1965, +6,35%; 1966-1970, +5,00%; and 1971-1975, +0,79%. The 1975 free world production level was 5 715 265 tonnes of zinc metal (down 1,3% from 1974) to which the following countries contributed: Canada, 20,6%; Australia, 8,3%; U.S.A., 7,5%; Peru, 6,4%; Mexico, 4,6%; Japan, 4,2%; and others, 48,4%. An alternate source suggests the total production of metal during 1975 to have been 4 464 000 tonnes, of which South Africa contributed 2,1% (95 000 tonnes of metal).

Reserves, Resources

In 1950, world zinc metal reserves were estimated to be 72 627 888 tonnes of which about 76% was in the free world. In 1973, the world reserves were estimated to be 235 million tonnes of metal; identified resources were gauged to be 1 510 million tonnes of metal of which 84,44% were thought to be subeconomic; and undiscovered resources were estimated at 3 575 million tonnes (90,35% subeconomic) giving a total world resource of 5 085 million tonnes (88,59% subeconomic). In 1975, estimates of the reserves were about 136 million tonnes to which the following countries contributed: Canada, 22,7%; U.S.A., 20,0%; Australia, 12,0%; Japan, 3,3%; Mexico, 2,9%; Peru, 2,3%; and other, 36,8%. On this basis, if the new South African demonstrated resources could be proved to be reserves, then South Africa contains 7,3% of world reserves. At the 1975 production rate, world reserves should last for about 24 years. Total world resources in 1975 were estimated to be 4 535 million tonnes of metal, most of which is contained in the Kupferschiefer bed of Europe, in deep-sea manganese nodules, in platform carbonate deposits and in massive sulphide deposits.

TRENDS, EVENTS, OUTLOOKS

Domestic

From 1964-1974 zinc consumption increased at a rate of 7,2% per annum. With the development of new mines in the north-western Cape, the production future appears to be bright and is expected to reach 250 000 tonnes of metal by the year 2000, which in terms of today's prices, will be worth R300 million. The demand at that date could be as high as 350 000 tonnes of metal. Based on Prieska's production and purchases of concentrate from South West Africa, the Zinc Corporation of South Africa Limited produces slab zinc at a plant situated at Springs in the Transvaal. To cope with the increased production from the new mines, it is currently poised to expand its present capacity of 80 000 tonnes per year.

World

Growth of world zinc consumption was about 5% for the decade prior to 1974. The severe economic recession brought an unprecedented fall (23%, but probably overstated as it does not take into account the running down on inventories by consumers) in zinc consumption during 1975. There were indications of recovery in demand at the end of that year and LME prices rose strongly during early 1976. There was no matching curtailment in mine production so that consumer stores of concentrates reached high levels during 1975 and curtailments in metal production of up to 40% were announced by many producers, so that competition for markets was strong.

The U.S. Government stockpile, LME warehouse stocks and producers stocks were up to total about 1,35 million tonnes. The whole outlook for zinc in 1975 was gloomy, with long-term projects for expanding or starting up new metal production being deferred. Although there are unlikely to be shortages during the next few years, no doubt there will be a strong and sharp improvement in demand when economic recovery gets under way. The growth in U.S. demand is estimated to increase at an annual rate of 2,6% per annum and that of the world at 3,5% per annum up to 1980, assuming a better balance between supply and demand and the utilization of accrued stocks. A greater effort by producers than ever before, is called for to stimulate consumption in a much more competitive climate.

ABSTRACTED STATISTICS AND COMPARISONS

Excluding petroleum as the only imported commodity, the relevant statistics pertaining to the other twenty commodities are abstracted in Table 1 which is self-explanatory.

Production

The 1975 South African production was valued according to 1975 export prices and the 1975 world production according to 1975 U.S. prices. Where only one price was available (Table 1), that figure was used. Total South African production of the twenty commodities in 1975 shows a value of Rm 5142,5021 and total world production of the twenty commodities, a value of Rm 75 072,2678. Based on value of the twenty commodities, South Africa's production of precious metals and diamonds comprised 50,49% of the world production, solid and nuclear fuels (coal and uranium), 2,54% of world production and base and industrial minerals 4,06% of world production. The total South African production of the twenty commodities was 6,85% of the total world production of the same commodities. Since the twenty commodities constitute some 89,7% of total estimated South African mineral production value, these figures are probably very close to the grand total of mineral production in South Africa and the world.

Production Distribution and Growth

Attempts were made at obtaining global figures for South African production distribution and annual growth for the combined twenty commodities for five year periods as in Table 1. Clearly straight averaging of the figures on Table 1 are not acceptable and some weighting according to volume and prices was necessary. Simple weighting of this type proved to be difficult for the following reasons:

- (a) Simple volume or weight could not be used since carats, for instance, cannot be compared with tonnes and a common basis for comparison is needed;
- (b) The value of production appears to load high-priced commodities of large production volume unfairly, especially a commodity such as gold;
- (c) Although tonnage of ore prior to any plant treatment has a common basis for comparison, it was found that this gave an unfair loading to commodities such as diamonds which shows very low concentration in the "ore" before treatment and extraction

The problem of weighting is probably not insurmountable, especially if tone-down parameters such as logarithmic values or sophisticated statistical treatments are used, but the eventual meaning of the data produced may become vague. Consequently these avenues were not pursued. For what they are worth,

the straight averages are quoted forthwith. The production distribution for 17 of the commodities is as follows: 1941-1945, 3,4%; 1946-1950, 4,6%; 1951-1955, 8,2%; 1956-1960, 12,2%; 1961-1965, 15,1%; 1966-1970, 20,8% and 1971-1975, 30,6%, with nickel, the platinum-group metals and zinc being excluded. The straight average of growth of 16 of the commodities (excluding lead, nickel, the platinum-group metals and zinc) averaged +10,55% as follows: 1941-1945, +8,93%; 1946-1950, +13,54%; 1951-1955, +11,43%; 1956-1960, +7,58%; 1961-1965, +7,43%; 1966-1970, +12,63% and 1971-1975, +12,32%. The same 16 commodities grew at an average rate of 10,79% from 1961-1975 in South Africa compared with an average annual world growth of 3,81% for the same commodities. This means that the average annual growth rate for the commodities was 2,77 times that of the world rate for the same commodities.

Price Movements

Straight averages of U.S. price increases for all the commodities are as follows: 1971-1975, +16,86% and 1961-1975, +8,05%.

Reserves, Resources

The valuation of the South African and world reserves plus resources for 19 of the commodities (tin excluded) was undertaken, using the same basis as for the 1975 production mentioned above (see production). The South African reserves plus resources show a value of Rm 2 209 118,5200 compared with a world value of Rm 178 521 419,9000 (19 commodities). The proportion of the South African reserves plus resources value compared with the world value (both for 19 commodities) was as follows: precious metals plus diamonds, 62,32%; solid and nuclear fuels (coal and uranium), 0,71%; base and industrial minerals, 4,28% and overall, 1,24%.

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REFERENCES

- Alberts, B.C., 1965. The supply of raw materials to the iron and steel industry. Iscor News, March, 1965 : 17-23.
- Anhaeusser, C.R., 1974. Archaean metallogeny in Southern Africa. Econ. Geol. Res. Unit., Inform. Circ. 91, Univ. Witwatersrand. also: Econ. Geol., (1976), 71(1) : 16-43.
- Averitt, P., 1973. Coal. U.S. Mineral Resources, Prof. Paper 820 : 133-142.
- Bailly, P., 1976. The problem of converting resources to reserves. Soc. Min. Eng. : 27-37.
- Baker, G., 1976. Resources of Southern Africa - Today and Tomorrow. Ass. Sci. Tech. Soc. S. A. Proc. of Conference : 402 pp.
- Bureau, P., 1976. Gold. Mining Annual Review : 27-31.
- Beerman's All Mining Yearbook, 1959-1973. Combined Publishers (Pty.) Limited, Johannesburg.
- Brobst, D.A. and Pratt, W.P., editors, 1973. United States Mineral Resources. Prof. Paper 820, U.S. Geol. Surv. : 722 pp.
- Brooks, D.P. and Andrews, P.W., 1974. Mineral resources, economic growth and world population. Science, v. 85 : 13-19.
- Cathcart, J.B. and Gulbrandsen, R.A., 1973. Phosphate deposits. U.S. Mineral Resources Prof. Paper 820 : 527-536.
- Chamber of Mines of South Africa, 1971. Pres. Address, 81st. Ann. Gen. Meeting.
- Chamber of Mines of South Africa, 1975. 86th. Ann. Report : 98 pp.
- Cilliers, J.J. le R., 1976. Mineral resources of Southern Africa - Resources of Southern Africa - Today and Tomorrow. Ass. Sci. Tech. Soc. S. Afr., Proc. of Conference : 293-303.
- Childs, F.E., 1975. Vermiculite. Mining Ann. Review : 126.
- Clay, J.A., 1976. Copper. Mining Ann. Review : 37-40.
- Coal, Gold and Base Minerals of Southern Africa, 1974. The "Black Mountain" turns to silver. v. 22 : 49-51.

- Coal, Gold and Base Minerals of Southern Africa, 1976. World coal output continues upward trend : 105-108.
- Coetzee, J.P., 1969. The activities of Iscor. S.A. Min. Eng. Jour., Comm. Vol. : 197.
- Commodity Data Summaries, 1960-1976. Bureau of Mines, U.S. Dept. Interior.
- Cornwall, H.R., 1973. Nickel. United States Mineral Resources, Prof. Paper 820 : 437-442.
- Cousins, C.A., 1964. The platinum deposits of the Merensky Reef. The Geology of Some Ore Deposits in Southern Africa. Geol. Soc. S. Afr., v. 2 : 225-237.
- Cousins, C.A. and Feringa, G., 1964. The chromite deposits of the western belt of the Bushveld Complex. Geol. Soc. S. Afr., v. 2 : 183-202.
- Cousins, C.A. and Vermaak, C.F., 1976. The contribution of South Africa ore deposits to the geochemistry of the platinum group metals. Econ. Geol., v. 71 : 287-305.
- Cox, D.P., Schmidt, R.G., Vine, J.D., Kirkemo, H., Tourtelot, E.G. and Fleisher, M., 1973. Copper. U.S. Mineral Resources, Prof. Paper 820 : 163-190.
- Davis, J.C., 1974. Debating fuel-reserve data. Chem. Eng. : 30-34.
- Day, S.D., 1976. Iron ore. Mining Ann. Review : 65-68.
- Dorre, J. v.N., Chittenden, M.D. and Worl, R.G., 1973. Manganese. U.S. Mineral Resources, Prof. Paper 820 : 385-400.
- Dunham, Sir K., 1974. How long will our minerals last? New Scientist, v. 61, No. 881 : 129-130.
- Energy in South Africa - a forecast, 1972. Department of Planning : 134 p.
- Financial Mail, 1975. Investment Guide Supplement, 14th Feb., 1975 : 27 p.
- Finch, W.I., Butler, A.P., Armstrong, F.C. and Weissenborn, A.E., 1973. Uranium. U.S. Mineral Resources, Prof. Paper 820 : 456-467.
- Fischer, R.P., 1973. Vanadium. U.S. Mineral Resources, Prof. Paper 820 : 679-688.
- Freeman, M.R., 1976. Phosphates. Mining Annual Review : 103-105.
- Foscot, 1968, 1974, Reports.
- Gordon, S., 1958. Economics and the conservation question. Jour. Law and Econ., v. 1 : 110-121.
- Gössling, H.W., 1974 and 1976. An updated summary of the world's fluorspar industry with special reference to South Africa. N.I.M. Reports 1668 and 1814, Johannesburg.
- Greathead, H.G., 1964. Chromium. Nat. Res. Div. Council, Pretoria.
- Grierson, A., 1976. Coal. Mining Annual Review : 85-89.
- Hammerbeck, E.C.I., 1971. Geochemical prospecting for lead and zinc in the western Transvaal. Geol. Surv. S. Afr., Bull. 53 : 18 pp.
- Hanekom, H.J., van Staden, C.M. v.H., Smit, P.J. and Pike, D.R., 1965. The geology of the Palabora Igneous Complex. Geol. Surv. S. Afr., Mem. 54.
- Heyl, A.V., Hall, W.E., Weissenborn, A.E., Stager, H.K., Puffett, W.P. and Reed, B.L., 1973. Silver. U.S. Mineral Resources, Prof. Paper 820 : 581-604.
- Hodge, B.L., 1976. Fluorspar. Mining Annual Review : 111-113.
- Hunter, D.R. and Lenthall, D.H., 1971. A preliminary review of tin mineralization with particular reference to the Bushveld Igneous Complex. Inform. Circ. 61, Econ. Geol. Res. Unit, Univ. Witwatersrand.
- I'Ons, D., 1976. Energy resources are not all fuel reserves. New Scientist, v. 70, No. 988 : 222-224.
- Jolly, J.H., 1976. The Minerals Industry of the Republic of South Africa. Minerals Yearbook, v. 3, Area Reports : 745-769.
- Keyfitz, N., 1976. World resources and the world middle class. Scientific American, v. 235 : 28-35.

- Klemic, H., James, L.J. and Eberlein, G.D., 1973. Iron. U.S. Mineral Resources, Prof. Paper 820 : 29-1306.
- Krüger, C.M., 1966. Ekonomiese en bedryfsaspekte i.v.m. die verwerking van delfstowwe tot yster en staal. *Teknikon*, v. 15 : 35-42.
- Kruparz, H. and van Rensburg, W.C.J., 1965. The chromite deposits at Nietverdient, Marico District, Transvaal. *Ann. Geol. Surv. S. Afr.*, v. 4 : 137-150.
- Lawrence, R.A., 1976. Mining has performed well in face of critical problems. *Coal, Gold and Base Min.*, July, 1976 : 6-7.
- Lenthall, D.H., 1974. Tin production from the Bushveld Complex. *Inform. Circ. 93, Econ. Geol. Res. Unit, Univ. Witwatersrand* : 15 p.
- Lloyd, B.C.J., 1976. Uranium. *Mining Annual Review* : 91-93.
- Martini, J.E.J., 1976. The fluorite deposits in the Dolomite Series of the Marico district, Transvaal, South Africa. *Econ. Geol.*, v. 71 : 625-635.
- Maxwell, D.G., 1976. Trends in the demand for minerals in Southern Africa. *Ass. Sci. Tech. Soc. S. Afr., Conference proc.* : 260-275.
- McCulloh, T.H., 1973. Oil and gas. U.S. Mineral Resources, Prof. Paper 820 : 477-496.
- McKelvey, V.E., 1974. Potential mineral reserves. *Resources Policy*, v. 2 : 75-81.
- Miller, M.H., 1973. Antimony. U.S. Mineral Resources, Prof. Paper 820 : 45-50.
- Mineral Facts and Problems, 1962-1973, U.S. Bureau of Mines, Bull. 630.
- Minerals Year Book, 1960-1973, U.S. Bureau of Mines, Vols. 1 to 4.
- Mining Annual Review, 1960-1976, Published by Mining Jour., London.
- Minerals, 1968-1975, Quarterly Information Circulars, Dept. of Mines, Reports for the Republic of South Africa.
- Mineral Industries of Africa, 1975, U.S. Bureau of Mines, Report for 1974-1975, Republic of South Africa : 85-87.
- Mining Magazine, 1974. Phelps Dodge to mine base metals in South Africa. April, 1974 : 239.
- Mineral Resources of South Africa, 1930, 1940, 1959, 1976. *Geol. Surv. S. Afr., Dept. of Mines, Pretoria*.
- Molyneux, T.W., 1972. A survey of the mineral deposits in, and related to the Bushveld Complex, South Africa. *Int. Geol. Congr., 24th Session, Sect. 4* : 225-232.
- Morris, H.T., Heyl, A.V. and Hall, R.B., 1973. Lead. U.S. Mineral Resources, Prof. Paper 820 : 313-332.
- Nel, H.J. and Luyt, J.F.M. 1964. Vanadium-rich magnetite seams of the Bushveld Igneous Complex, South Africa (Abstr). *Econ. Geol.*, v. 59 : 1416.
- Newman, S.C., 1973. Platinum. *Trans. Inst. Mins. Metall.*, London, v. 82 : A52-A68.
- Ortlepp, R.J., 1962. Manganese. *Nat. Res. Dev. Council, Pretoria*.
- Page, N.J., Clarke, A.L., Desborough, G.A. and Parker, R.L., 1973. Platinum-group metals. U.S. Mineral Resources, Prof. Paper 820 : 537-546.
- Petrick, A.J., van Rensburg, W.C.J. and Vos, A.D., 1975. The report of the Commission of Enquiry into the coal resources of the Republic of South Africa. Govt. Printer, Pretoria.
- Prast, W.G., 1976. Prospects for the U.S. Uranium Industry. *Min. Mag.* : 349-357.
- Pretorius, D.A., 1974. The nature of the Witwatersrand gold-uranium deposits. *Econ. Geol. Res. Unit, Inform. Circ. 86, Univ. Witwatersrand*.
- Pretorius, D.A., 1974. Gold in the Proterozoic sediments of South Africa : systems, paradigms and models. *Econ. Geol. Res. Unit, Inform. Circ. 87, Univ. Witwatersrand*.
- Pretorius, D.A., 1975. The depositional environment of the Witwatersrand goldfields : a chronological review of speculations and observations. *Econ. Geol. Res. Unit, Inform. Circ. 95, Univ. Witwatersrand*.

Rand Daily Mail, 6 August, 1975. Quotations from Phelps Dodge Report.

Resources for Freedom, 1952. The report of the President's Materials Policy Commission, vols. 1 to 5 inclusive. U.S. Govt. printing office.

Robinson, R.E., 1976. Metallurgical problems of the future. Ass. Sci. Tech. Soc. of S. Afr., Proc. of Conference, Johannesburg : 308-316.

Roux, A.J.A., 1976. Uranium demand - an exploration challenge. S.A. Digest : 5.

Salamon, M.D.G., 1976. Technological problems in mining and their implications. Ass. Sci. Tech. Soc. S. Afr., Proc. of Conference : 304-307.

Sainsbury, C.L. and Reed, B.L., 1973. Tin. U.S. Minerals Resources, Prof. Paper 820 : 637-652.

Schutte, F.J.P., 1975. Reports - Geol. Surv. S. Afr. (unpublished).

Shearer, R.W., 1976. Metals in South Africa - present and future. Unpub. report.

Shridge, A.F., 1973. Asbestos. U.S. Mineral Resources, Prof. Paper 820 : 63-74.

Simons, F.S. and Prinz, W.C., 1973. Gold. U.S. Mineral Resources, Prof. Paper 820 : 263-276.

S.A. Mining and Eng. Journal, 1976. Vanadium surges ahead, Aug., 1976 : 32-37.

S.A. Mining and Eng. Journal, 1976. Politics hinder mineral exploration, Aug., 1976 : 44-47.

S.A. Mining and Eng. Journal, 1976. S.A. may become important phosphate suppliers, Aug., 76 : 52-65.

Strauss, S.D., 1976. Silver. Mining Annual Review : 31-33.

Stubbs, R.L., 1976. Lead and Zinc. Mining Annual Review : 45-49.

Thayer, T.P., 1973. Chromium. U.S. Mineral Resources, Prof. Paper 820 : 111-112.

The Strategic Role of Mineral Resources, 1976. Collection of papers delivered at the Mbabane Congress, Swaziland, June 7-10, 1976.

Thompson, A.G., 1976. Manganese. Mining Annual Review : 74-75.

Thompson, A.G., 1976. Chromite. Mining Annual Review : 75-77.

Thompson, A.G., 1976. Vanadium. Mining Annual Review : 81-82.

Van der Merwe, M.J., 1976. The layered sequence of the Potgietersrus Limb of the Bushveld Complex. Econ. Geol., v. 71 : 1337-1351.

Van Rensburg, W.C.J., 1966. Die reserwes en ontginningsmoontlikhede van Suid-Afrika se ferrometaalafsettings. Tegikon, v. 15 : 29-34.

Van Rensburg, W.C.J., 1975. "Reserves" as a leading indication of future mineral production. S.A. Inst. of Intern. Affairs publ. : 34 pp.

Van Rensburg, W.C.J., 1976. Mineral resources of Southern Africa. Ass. Sci. Tech. Soc. S. Afr., Proc. of Conference, Johannesburg : 276-292.

Van Rensburg, W.C.J. and Beukes, T.E., 1974. An assessment of the mineral occurrences of the north-western Cape. Rep. 1957, Nat. Inst. Met., Johannesburg.

Van Rensburg, W.C.J., Bishopp, D.W. and Savage, W.H.D., 1969. South Africa's coal resources. S.A. Coal Advisory Board.

Vermaak, C.F., 1976. Nickel. Mineral Resources of the Republic of South Africa, Handbook 7, Geol. Surv. of S. Afr. : 177-182.

Vermaak, C.F., 1976. The nickel pipes of Vlakfontein and vicinity, western Transvaal : Econ. Geol., v. 71 : 261-286.

Vermaak, C.F., 1976. The Merensky Reef - thoughts on its environment and genesis. Econ. Geol., v. 71 : 1270-1298.

Verwoerd, W.J., 1967. The carbonatites of South Africa and South West Africa, Handbook 6, Geol. Surv. S. Afr.

- Von Backström, J.W., 1974. Review of uranium reserves and exploration - Lecture on 21st March, 1974, at symposium on uranium prospecting. S. Afr. Atomic Energy Board.
- Von Backström, J.W., 1976. Uranium. Mineral Resources of the Republic of South Africa, Handbook 7, Geol. Surv. of S. Afr. : 233-240.
- Von Gruenewaldt, G., 1976. Sulfides in the Upper Zone of the eastern Bushveld Complex. Econ. Geol., v. 71 : 1324-1336.
- Von Gruenewaldt, G., 1976. An evaluation of the mineral resources of the Bushveld Complex. Research Report, Inst. for Geol. Res. on the Bushveld Complex, Univ. Pretoria.
- Wagner, P.A., 1929. The platinum deposits and mines of South Africa. Cape Town, 2nd impression, 1973 : 338 pp.
- Wagner, P.A., 1928. The iron deposits of the Union of South Africa. Mem. 26, Geol. Surv. S. Afr.
- Watson, M.D. and Snyman, C.P., 1975. The geology and mineralogy of the fluorite deposits at the Buffalo fluorspar mine on Buffelsfontein 347 KR, Naboomspruit district. Trans. geol. Soc. S. Afr., v. 78 : 137-151.
- Way, H.J.R., 1976. Antimony. Mining Annual Review : 109-110.
- Wedow, H., Kiilsgaard, T.H., Heyl, A.V. and Hall, R.B., 1973. Zinc. U.S. Mineral Resources, Prof. Paper 820 : 697-712.
- Whillier, J., 1975. Platinum. S.A. Min. Eng. Jour. : 32-37.
- Willemse, J., 1969. The vanadiferous magnetic iron-ore of the Bushveld Igneous Complex. Econ. Geol., Mon. 4 : 187-208.
- Wood, R.A., 1971. Lecture at National Institute for Metallurgy, Johannesburg.
- Worl, R.G., van Alstine, R.E. and Shawe, D.R., 1973. Fluorine. U.S. Mineral Resources Prof. Paper 820 : 223-237.
- World Mining, 1976. Uranium prospecting today - what to expect tomorrow - Part 1 : 48-54.
- Zietsman, A.L., 1973. Die beskikbare ystererts reserwes in Suid-Afrika en in die besonder YSKOR se reserwes - Iscor report.
- Zwartendyk, J., 1972. What is "mineral endowment" and how should we measure it. Min. Res. Branch, Canad. Dept. of Energy, Mines and Resources, Bull. MR124 : 17 pp.
- Zwartendyk, J., 1974. The life index of mineral reserves - a statistical mirage. C.I.M. Bull. : 67-68.

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APPENDIX

Standards

Throughout this report, the metric system of weights and measures was utilized where possible. Unfortunately quoted sources are often vague regarding the system being used, requiring some numerical separation in the text: thus "tonnes" have been used, where metric tonnes are implied or where imperial tonnes have been converted, while the use of "tons", as such, indicate that uncertainty exists regarding what system of weights and measures were utilized by the source quoted. Standard conversion factors for the Metric and Imperial Systems and South African and U.S. Units were used according to Kayser, 1971 (Metric and other conversion factors: J.M. Kayser: Purnell and Sons (Pty.) Limited, Cape Town, Johannesburg, London). Parity for the South African Rand versus the U.S. dollar was used throughout the text as for the pre-devaluation 1975 rand as follows: R1 = \$1,4761 or \$1 = R0,6729. The only exception to the consistent use of metric units was in petroleum, where the standard U.S. barrel was preferred above the use of megalitres because of the barrel-measure dependence on specific gravity, its different use in the Imperial System and the volume of work in converting a mass of data quoted by U.S. sources. All other standards are as quoted in the text.

Reserves, Resources

Definitive inconsistencies have been stressed above but the following definitions were used where applicable in the text:

- (a) Resource: concentration of naturally occurring solid, liquid or gaseous materials in or on the earth's crust in such form that the economic extraction of the commodity is currently or potentially feasible. Total resources comprise identified or known materials plus those yet undiscovered but which, on the basis of geological evidence, are presumed to exist.
- (b) Identified resource: specific bodies of mineral-bearing material whose location, quality and quantity are known from geological evidence, supported by engineering measurements, with respect to the demonstrated category. This definition was used for S.A. resources. In the case of world identified resources, this category is more general, as follows: specific identified mineral deposits that may or may not be evaluated as to extent or grade and whose contained minerals may or may not be profitably recoverable with existing technology and economic conditions.
- (c) Undiscovered resource: unspecified bodies of mineral-bearing material surmised to exist on the basis of broad geological knowledge or theory.
- (d) Reserves: that portion of identified resources from which a useable mineral or energy commodity can be economically and legally extracted at the time of determination. The term "ore" is also used for reserves of some minerals. It is the total of measured, indicated and inferred resources (see below).

The best demonstrations of the meaning of all resources definitions are provided by McKelvey (1974) and Brobst and Pratt (1973), although a comprehensive documentation of alternate schemes is provided by van Rensburg, 1975. Certain qualifying adjectives are applied both to the reserves and the identified but subeconomic resource components as follows:

- (a) Measured: material for which quality and quantity estimates (20% margin of error) have been computed from analyses and measurements at closely-spaced and geologically documented sample sites.
- (b) Indicated: material for which estimates of quality and quantity have been computed partly from sample analyses and measurements and partly from reasonable geological projections.

With regard to the traditional terms, "proved" and "measured" are essentially synonymous, but "probable" and "possible" are not necessarily respectively synonymous with "indicated" and "inferred". Demonstrated is a collective term for the sum of materials in both measured and indicated resources while inferred resources included material in unexplored but identified deposits of which the quality and size are based on geological evidence and projection.

Identified subeconomic resources are known deposits which are not currently economically mineable as follows:

- (a) Paramarginal: a portion of subeconomic resources that either borders on being economically exploitable or is not commercially available because of legal or political circumstances.
- (b) Submarginal: a portion of subeconomic resources that would require a substantially higher price (more than 1,5 times ruling prices at the time of determination) or a major cost-reducing advance in technology.

The abovementioned are also called "conditional" resources (not profitably recoverable under existing technological and economic conditions) although often the production and resource of a mineral commodity may be conditional upon the production of a higher-priced commodity to which it is a co-product (i.e. silver is a reserve or resource conditional on the production of Witwatersrand gold).

Moving towards decreasing geological confidence and uncertainty of resource existence, we have the following resources:

- (a) Hypothetical: undiscovered materials or mineral deposits, whether of recoverable or subeconomic grade, which are reasonably geologically predictable and may exist in a known mining district under known geological conditions. Exploration that confirms their existence and reveals their quantity and quality, will permit their reclassification as a reserve or as an identified but subeconomic resource. In practice, hypothetical-resource estimates are based on the magnitude of identified resources, times a factor assigned according to the geological favourability of a region and the extent of geological mapping or exploration.
- (b) Speculative: undiscovered materials or mineral deposits, whether of recoverable or subeconomic grade, that may exist in known types of deposits in districts with a favourable geological setting where no discoveries have been made up to the present, or as yet unknown or unconventional types of deposits that remain to be recognized in unknown districts. Exploration that confirms their existence and reveals quantity and quality would permit their reclassification as reserves or identified but subeconomic resources.

A term that is often used is that of "potential resources" which usually applies to the sum of hypothetical and speculative resources. Other meanings may be : identified mineral deposits not profitably recoverable under existing technology and economic conditions and undiscovered mineral deposits whether of recoverable or subeconomic grade.

Depletion Allowance

A proportion of income derived from mining or oil production that is considered to be a return of capital not subject to Income Tax.

Commodity Prices

Prices of commodities and their escalation through time are probably the most unfavourable statistic in the minerals industry since they are subject to inflationary trends and numerous political and social factors etc. which, although influencing prices, have virtually nothing to do with the actual minerals economy (as the current slump and the oil prices have indicated). The only method would be to accept prices at a fixed parity; but where this has been done it shows some surprising aspects. Cox and others (1973) have tested this for copper and it shows the following variation in the average equivalent (1970 dollars) annual price in cents per pound and the actual price shown in parenthesis: 1900, \$63,5 (\$16,19); 1910, \$43,5 (\$12,73); 1920, \$30,0 (\$17,45); 1930, \$32,5 (\$12,98); 1940, \$29,5 (\$11,29); 1950, \$30,0 (\$21,32); 1955, \$41,0 (\$37,49); 1960, \$36,5 (\$32,05); 1965, \$39,9 (\$35,02) and 1970, \$58,2 (\$58,20). This shows that actual annual-price fluctuations are only marginally applicable to fixed-price annual fluctuations, the fixed price showing an average increase of $+0,28 \pm 2,94\%$ per annum compared with actual price average increase of $+2,82 \pm 4,45\%$ per annum. In fact, the fixed-price variation is much greater than the actual-price variation (coefficient of variation about 104% and 148% respectively).

Area Identification

In situations concerning world production and resources, countries have been lumped together as follows:

- (a) Central Economy Countries: centrally-controlled-economy (communist) countries, including Albania, Bulgaria, China (Peoples Republic of), Cuba, Czechoslovakia, East Germany, Hungary, Mongolia, North Korea, North and South Vietnam, Poland, Rumania, U.S.S.R. and Yugoslavia.
- (b) Market Economy Countries: countries which sell their minerals or metals on a free market i.e. the free-world countries. Note that Angola, Mocambique etc. were regarded as free-world countries during 1975.

* * * * *

TABLE 1

COMPARISON AND RANKING OF TWENTY MINERAL COMMODITIES PRODUCED IN SOUTH AFRICA
AND THEIR STATUS IN THE WORLD'S MINERAL INDUSTRY

(Abbreviations: t = metric tonnes; mt = millions of tonnes; kg = kilograms; mkg = millions of kilograms
 c = metric carats; m.c. = millions of carats; Rm = millions of rands;
 (w) = world figures; n.a. = not available; n.s. = no significance; e = estimate).
 Definitions of reserves and resources types are supplied in the Appendix.

ITEM	ANTIMONY	ASBESTOS	CHROMIUM	COAL	COPPER
<u>PRODUCTION</u>					
RSA Production, 1975	16 000t	0,3547mt	2,0754mt	69,4396mt	0,175mt
World Production, 1975	73 028t	3,734mt	7,3500mt	2942,5mt	6,624mt
% of World Production, 1975	21,91%	0,09%	28,24%	2,36%	2,64%
RSA % of Production, 1941-45	2,5%	2,6%	3,6%	7,8%	5,0%
1946-50	6,6%	4,1%	6,9%	9,1%	6,2%
1951-55	14,1%	9,2%	10,9%	10,6%	7,7%
1956-60	15,1%	13,5%	11,5%	13,5%	9,6%
1961-65	17,1%	17,6%	15,9%	16,2%	11,0%
1966-70	22,0%	23,0%	20,3%	19,2%	26,2%
1971-75	22,6%	30,0%	30,9%	23,6%	34,3%
% Annual Growth	+94,60%	+ 1,48%	-13,13%	+ 6,18%	+ 7,73%
1946-50	+29,90%	+29,22%	+43,97%	+ 2,42%	+ 6,71%
1951-55	+50,94%	+ 8,79%	+ 2,83%	+ 3,64%	+ 7,74%
1956-60	- 4,05%	+ 8,24%	+ 2,17%	+ 3,56%	+ 0,79%
1961-65	+11,04%	+ 6,76%	+11,87%	+ 4,90%	- 6,12%
1966-70	+ 6,11%	+ 5,91%	+ 2,92%	+ 2,47%	+25,14%
1971-75	- 0,20%	+ 3,93%	+14,81%	+ 4,96%	+ 3,76%
Growth Ranking 1971-75	16	14	7	13	15
Average Annual Growth 1941-75	+26,90%	+ 9,19%	+ 9,35%	+ 4,02%	+ 8,28%
Growth Ranking 1941-75	2	12	11	16	13
World Annual Growth 1961-75	+ 2,25%	+ 4,58%	+ 3,73%	+ 3,92%	+ 3,42%
Export Price, 1975R/Unit	R1 486,04	R312,13	R22,95	R13,90	R817,69
U.S. Price, 1975R/Unit	R2 596,10	R135,00	R29,80	R13,91	R795,15
U.S. Price Movement 1971-75	+22,00%	+13,66%	+15,80%	+25,99%	+ 5,14%
1961-75	+16,22%	+ 4,25%	+ 7,97%	+ 9,95%	+ 5,78%
Production Value, lowest Price, Rm.	R23,7766	R47,8858	R47,6304	R965,2104	R139,1512
Value Ranking	14	12	13	2	8
Production/Total Sales Value	0,57%	1,16%	1,15%	23,35%	3,36%
Projected Production to 1980-85	3,5%(w)	n.a.	9,4%	3,2%	7,9%
to 2000	3,5%(w)	n.a.	5%	4,0%	6,0%
<u>RESERVES, RESOURCES</u>					
Reserves, Indicated	125 000t	-	-	58 250mt	476 500t
Reserves Inferred		7,1mt	2 333mt	23 274mt	1,0mt
Resources, Identified.	175 000t	-	2 083mt	-	13,3255mt
Hypothetical		6,9mt	3 048mt	-	-
World Reserves	4,3mt	87,09mt	4 344mt	n.a.	408,233mt
World Resources	1,45mt	48,00mt	3 639mt	11 421 156mt	1451
RSA % of World	2,64%	8,15%	71,5%	0,4%	3,74%
RSA Inferred Life, Years*	8-22	20-30	1 124	1 000	75
World Inferred Life, Years*	60	25	604	3 880	68

* Based on 1975 production.

TABLE 1 (Continued)

ITEM	DIAMOND	FLUORSPAR	GOLD	IRON	LEAD
PRODUCTION					
RSA Production, 1975	7,2951mc	0,202583mt	713 447kg	12,2978mt	3 605t
World Production, 1975	49,3827mc	4,732mt	940 000kg	875,000mt	3,351mt
% of World Production, 1975	14,77%	4,28%	75,30%	1,40%	0,11%
RSA % of Production, 1941-45	1,7%	0,8%	9,4%	2,4%	4,7%
1946-50	4,9%	1,0%	8,2%	4,4%	8,8%
1951-55	9,5%	3,5%	9,0%	6,0%	18,8%
1956-60	10,7%	11,2%	13,0%	8,2%	17,5%
1961-65	16,7%	15,0%	19,1%	15,5%	1,2%
1965-70	28,0%	24,8%	22,1%	25,9%	0,1%
1971-75	28,5%	43,7%	19,2%	37,6%	48,9%
% Annual Growth	+74,25%	- 9,98%	- 2,66%	+ 6,99%	n.a.
1946-50	+ 9,96%	+16,42%	- 0,88%	+ 6,93%	n.a.
1951-55	+ 9,61%	+37,67%	+ 4,71%	+11,39%	n.a.
1956-60	+ 3,45%	+30,36%	+ 8,41%	+ 9,45%	n.a.
1961-65	+12,53%	- 4,59%	+ 7,48%	+14,00%	n.a.
1966-70	+10,20%	+21,66%	+ 1,04%	5,50%	n.a.
1971-75	- 1,89%	+12,08%	- 6,50%	+11,84%	+383,64%
Growth Ranking 1971-75	18	9	20	10	2
Average Annual Growth 1941-75	+16,87%	+14,80%	+ 1,66%	+ 9,44%	(97,70%) n.s.
Growth Ranking 1941-75	5	6	17	10	-
World Annual Growth 1961-75	+ 1,88%	+ 5,96%	- 1,30%	+ 4,27%	+ 2,50%
Export Price, 1975R/Unit	R21,74	R53,17	R3 588,77	n.a.	R28,84
U.S. Price, 1975R/Unit	n.a.	R70,87	R3 510,15	R12,33	R320,43
U.S. Price Movement 1971-75	+ 1,99%	+ 5,39%	+37,43%	+11,69%	+ 7,87%
1961-75	+ 0,04%	+ 6,16%	+12,85%	+ 3,53%	+ 5,08%
Production Value, lowest Price, Rm.	R158,5955	R10,7713	R2 560,396	R151,6319	R0,1040
Value Ranking	5	16	1	7	20
Production/Total Sales Value	3,83%	0,26%	61,93%	3,67%	0,002%
Projected Production to 1980-85	n.a.	19,0%	n.a.	8,45%	20,0%
to 2000	n.a.	19,0%	n.a.	7,4-8,3	20,0%
RESERVES, RESOURCES					
Reserves, Indicated	-	-	-	-	-
Reserves, Inferred	50mc	{ 30mt	18,66mkg	6 500mt	5,61mt
Resources, Identified.	-	-	-	-	0,724mt
Hypothetical	-	-	-	5 100mt	-
World Reserves	1050mc	105mt	-	263 156mt	145,149mt
World Resources	n.a.	762mt	41,99mkg	772 195mt	large
RSA % of World	4,76%	27,6%	59,2%	1,12-2,47%	3,86%
RSA Inferred Life, Years*	13	148	21-26	163	1 757(?)
World Inferred Life, Years*	21	22	34	300	43

* Based on 1975 production.

TABLE 1 (Continued)

ITEM	MANGANESE	NICKEL	PHOSPHATE	P.G.METALS	SILVER
<u>PRODUCTION</u>					
RSA Production, 1975	5,863mt	20 754t	11,6261mt	83 979kg	0,95923mkg
World Production, 1975	22,498mt	745 252t	105,8685mt	180 431kg	8,80mkg
% of World Production, 1975	18,10%	2,78%	10,98%	46,50%	1,09%
RSA % of Production, 1941-45	2,6%	n.a.	-	n.a.	9,4%
1946-50	4,5%	n.a.	0,6%	n.a.	8,1%
1951-55	7,6%	n.a.	1,4%	n.a.	8,7%
1956-60	9,0%	n.a.	2,8%	n.a.	12,9%
1961-65	14,0%	n.a.	6,2%	n.a.	18,9%
1966-70	20,2%	n.a.	20,1%	n.a.	19,6%
1971-75	42,1%	n.a.	68,9%	n.a.	22,4%
% Annual Growth	1941-45	-18,37%	+ 0,66%	-	+ 3,09%
	1946-50	+56,50%	+12,84%	+10,02%	+12,66%
	1951-55	- 5,08%	+23,15%	+25,72%	+28,06%
	1956-60	+15,34%	n.a.	+13,54%	n.a.
	1961-65	+ 5,81%	n.a.	+ 9,01%	+26,82%
	1966-70	+11,01%	n.a.	+26,31%	+16,40%
	1971-75	+17,79%	+15,18%	+69,83%	+14,72%
Growth Ranking	1971-75	5	6	3	8
Average Annual Growth	1941-75	+11,86%	+12,96%	25,74%	+16,96%
Growth Ranking	1941-75	8	7	3	4
World Annual Growth	1961-75	+ 4,00%	+ 5,55%	+ 8,20%	+14,52%
Export Price, 1975R/Unit		n.a.	n.a.	R19,34	R2 828,23e
U.S. Price, 1975R/Unit		R42,95	R3 122,74	R13,35	R2 863,14e
U.S. Price Movement	1971-75	+20,89%	+10,21%	+33,14%	+10,50%
	1961-75	+ 4,50%	- 7,36%	+11,86%	+ 6,88%
Production Value, lowest Price, Rm.		R251,8373	R64,8093	R155,2084	R237,5119
Value Ranking		3	10	6	4
Production/Total Sales Value		6,09%	1,57%	3,75%	5,74%
Projected Production to					
1980-85		5,1%	2,8%	10,0%	2,8%
to 2000		5,1%	2,8%	10,0%	2,8%
<u>RESERVES, RESOURCES</u>					
Reserves, Indicated	-	-	(P ₂ O ₅)	-	1,5 mkg
Reserves, Inferred	3 000mt	20,8mt	{	62,89mkg	6,633mkg
Resources, Identified.	3 000mt	-	{ 1 050mt		1,000mkg
Hypothetical	2 000mt	large	large?	large	-
World Reserves	5 380mt	53,977mt	16 066mt	17,47mkg	189,731mkg
World Resources	17 700mt	63,503mt	large	55,99mkg	large
RSA % of World	37,1%	42,24%	6,5%	71,2%	4,28%
RSA Inferred Life, Years*	512	1 000	90	714	95
World Inferred Life, Years*	239	72	152	97	22

* Based on 1975 production.

TABLE 1 (Continued)

ITEM	TIN	URANIUM	VANADIUM	VERMICULITE	ZINC
PRODUCTION					
RSA Production, 1975	4 534t	2,8095mkg	14 968t	207 529t	68 917t
World Production, 1975	217 434t	22,362mkg	20 411t	509 838t	5,7152mt
% of World Production, 1975	1,60%	12,56%	41,30%	37,4%	1,20%
RSA % of Production	1941-45 1946-50 1951-55 1956-60 1961-65 1966-70 1971-75	4,7% 4,8% 11,6% 15,7% 16,3% 18,5% 28,4%	- - 5,9% 31,2% 23,9% 19,7% 19,3%	- - - 2,2% 11,7% 18,8% 67,3%	- - 5,5% 12,1% 20,1% 25,3% 37,0%
% Annual Growth	1941-45 1946-50 1951-55 1956-60 1961-65 1966-70 1971-75	- 3,84% + 7,49% +19,09% + 1,37% + 2,35% + 3,93% +10,13%	- - - +14,98% -13,66% + 7,26% - 5,36%	- - - - +24,99% +13,78% +52,12%	- - - + 4,75% +13,10% + 1,62% +11,30% 725,47%
Growth Ranking	1971-75	12	19	4	11
Average Annual Growth	1941-75	+ 5,79%	(1956-75)	(1961-75)	(1956-75)
Growth Ranking	1941-75	14	18	1	15
World Annual Growth	1961-75	+ 0,92%	- 3,10%	+ 6,49%	+ 4,95%
Export Price, 1975R/Unit	R3 662,05	n.a.	n.a.	R30,43	R139,18
U.S. Price, 1975R/Unit	R5 132,87	R32,64	R4 094,43	R31,15	R580,0
U.S. Price Movement	1971-75 1961-75	+18,36% +10,34%	+35,85% +15,50%	+ 7,76% + 8,21%	+ 5,48% + 7,25% +22,87% + 8,96%
Production Value, lowest Price, Rm.	R16,6037	R91,7021	R61,2854	R6,3151	R9,5919
Value Ranking	15	9	11	19	18
Production/Total Sales Value	0,40%	2,22%	1,48%	0,15%	0,23%
Projected Production to					
1980-85	1,8%	15,5%	14,9%	n.a.	5,2%
to 2000	1,0%	6,9%	4,0%	n.a.	5,3%
RESERVES, RESOURCES					
Reserves, Indicated	n.a.	238 600t	3,249mt	80mt	
Reserves, Inferred	n.a.	-	{10,304mt	-	10,933mt
Resources, Identified.	n.a.	351 553t	{	large?	1,700mt
Hypothetical	n.a.	-	very large	-	-
World Reserves	10,3638mt	1,1793mt	34,623mt	172,365mt	136mt
World Resources	27,48mt	-	large	-	5 085mt
RSA % of World	-	20,23%	9,38%	39,5%	8,03%
RSA Inferred Life, Years*	-	85	713	385	183
World Inferred Life, Years*	38	53	1 696	338	24

* Based on 1975 production.