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MINERAL RESOURCES OF AUSTRALIA

1976

by

L.C. Noakes and J. Ward

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INTRODUCTION

This paper, designed for Industrial Mobilisation Courses in 1976, attempts to give a broad picture of Australia's mineral industry, and of the varied and widespread resources on which it is founded. It includes a quick glance at the history of the industry and the domestic requirement for the principal minerals and ores, some notes on the chief deposits and centres of production, reference to some of the industrial activities dependent on minerals, remarks about recent important events in mineral exploration, and an attempt to foresee what lies ahead. Two important minerals, coal and underground water, are being dealt with by other speakers to the Course and, though both are of vital importance to the national economy, they will not be included in the present discussion.

Even with these exceptions, the topic is still very large. Australia's known mineral wealth has increased with every decade since the first major discoveries more than a century ago, and the end still seems far from sight. Our growth as a nation has owed much in the past to the flow of population and capital which followed the early mineral discoveries. This flow reached a peak towards the end of the last century, then slackened for almost fifty years; it began again in the last two decades in the wake of exciting discoveries from which great new sources of wealth are already evident.

This new era in mineral development in Australia with its rash of discoveries and subsequent exploitation stemmed from many related factors – new exploration tools and concepts, the introduction to Australia of foreign capital and expertise, the rise of Japanese markets, and the advent of bulk carriers, to name a few - and has resulted in recent years in the mining industry replacing wool as a mainstay of the economy at a time when rural industries in general were depressed. Statistics available do not indicate the real contribution of the mineral industry to G.D.P. but the value of exports of industrial groups within Australia, given in Table 1, show the rising impact of the mineral industry on overseas funds as the largest single export earner in recent years. The contribution of mines and quarries in 1974-75 given as 26.9% of all exports is in fact higher, because the industrial classification used in Table 1 allocates some exports by the smelting and refining sections of the industry to "manufactures". For example, if the value of alumina is added to mineral exports the contribution rises to 30.4%.

However, the mineral industry cannot be seen in perspective without identifying problems as well as achievements; the need for additional reserves of crude oil is urgent; the use of foreign capital in both exploration and development has eroded Australian equity in the industry; restricted domestic markets for processed products, amongst other factors, continue to place restraints on mineral processing; and the prosperity of the industry, inevitably based on exports although benefiting from long-term contracts, remains heavily dependent on the Japanese economy, which currently provides markets for 52% by value of our mineral exports. Indeed the slowing down of the Australian mineral industry in 1975-76, as a result of lower world metal prices and of checks to the economy of both USA and Japan in particular, serves as a salutory reminder of our vital concern with world economies and of our need to diversify our mineral trade as much as possible.

Reactions from Australian and foreign stock exchanges, the inevitable failure of some ill-equipped small mining companies, and other regrettable but spectacular events following recent boom years tended to exaggerate the situation and to obscure the facts that in terms of development and production the industry has continued to progress. The phenomenal rate of annual increase in production has been lowered but not reversed. The value of ex-mine production and of exports continued to rise in 1972, 1973, 1974 and 1975 and on evidence to date will continue to rise in 1976. The level of exploration funds declined in 1974 and probably again in 1975; it is important that this trend be reversed if Australia is to be provided with the additional ore deposits required for continued development of the mineral industry in the 80's, and is to be able to make proper assessments of its resources.

One feature of the new epoch, perhaps worthy of comment, is the degree to which Governments have become involved with industry in both exploration and development of major mineral deposits.

In the twenty years to 1973 both State and Commonwealth Governments encouraged private enterprise from both domestic and foreign sources to carry out detailed prospecting and development aided by governmental contributions through regional mapping and other fundamental scientific work and by financial assistance in some specific area. In recent years, both State and Commonwealth Governments have become more concerned with the details and the timing of mineral development. The end of 1972 brought important changes in minerals policy under a Labor Government, with emphasis on Australian ownership of mineral resources; these changes included the establishment of a Pipeline Authority to purchase and distribute natural gas throughout the continent, restrictions on the inflow of foreign funds and on exploration by foreign companies, and proposals which were submitted to the Commonwealth Parliament in late 1973 to strengthen the Australian Industry Development Corporation (AIDC) and to establish a Petroleum and Minerals Authority.

In the event, these changes in policy which included reduced taxation incentives, brought some confusion and indecision to the mineral industry because new guidelines were not clearly established although this was underway at the end of 1975 when however, the Labor Government was replaced by a new Liberal administration. The Labor proposals for revision of the AIDC and for the establishment of the Petroleum Mineral Authority were never passed by the Senate although the nucleus of a PMA did invest some $2.9 million in the Australian mineral industry up to late 1975. The new Liberal Government stated that they would abolish the PMA and reorganise the Pipeline Authority. However, they have adopted guidelines for foreign investment in the Australian mineral industry along the lines of those announced by the Labor Government which called for 50% Australian equity in the development stage.

At the end of these notes reference is made to some of the policies followed in recent years with the intention of encouraging development or of conserving national resources. Attached also is a summary of ore reserves and of mineral processing in Australia as an indication of both resources and processing facilities. Overseas trade in minerals and mineral sufficiency are illustrated in the diagram showing values of imports and exports of minerals in 1974, which is attached at the end of the report. The table and diagram are perhaps more effective in illustrating the present situation than any amount of text can hope to be.

The minerals discussed are grouped under the following headings -

(a) Iron, manganese, chromium and other metals commonly used in the manufacture of steel;

(b) Base metals - copper, lead, zinc, and tin;

(c) Uranium, thorium, and other metals used in or in connection with the production of nuclear energy;

(d) Beach sand minerals - rutile, ilmenite, zircon;

(e) Other metals;

(f) non-metallic minerals;

(g) Fertilizer minerals;

(h) Petroleum (i.e. oil and natural gas).

Mineral statistics given are those for 1974, the latest calendar year for which complete figures are available.

The writers gratefully acknowledge generous assistance from their colleagues in the Mineral Economics and Petroleum Technology Sections, Mineral Resources Branch, in updating information and statistics contained in this paper.

DEVELOPMENT OF THE MINERAL INDUSTRY

The Australian mineral industry is in reality as old as the nation itself; it started with the first quarrying and shaping of Hawkesbury Sandstone for early buildings at Sydney Cove. But subsequent development of the Australian mineral industry can be conveniently divided into four stages - early settlement and exploration from 1788 to 1851, establishment of the mineral industry, 1851 to about 1910, the lean years from 1910 to about 1950, and the mineral boom which followed.

It is significant that these are not only local stages; they can be broadly identified in other countries with a sufficiently long history of the mineral industry like USA and Canada. Indeed, episodic discovery and development within mineral industries relate to a number of basic controls of which by far the most important are the levels of technology in exploration, mining and treatment.

Early Settlement and Exploration

The first recognition of mineral wealth followed soon after settlement and inevitably concerned coal, as the settlement of Sydney lay toward the centre of a coal basin with coal existing at depth and cropping out along the coast to both north and south. It was first discovered in the Newcastle area by escaped convicts in 1791; discovery of coal on the south coast followed a few years after and the first mines came into action near Newcastle in 1799. Indeed coal provided the first mineral export from Australia in 1800.

However, this first stage of development lacked emphasis on mineral resources, apart from coal, for a number of reasons. At that time, Britain was not seeking mineral supplies overseas and did not encourage the young colony to explore for minerals. Moreover, the colony first established as a penal settlement, was preoccupied in early years in learning how to feed itself with little interest in mineral deposits; partly for this reason scientific contributions to exploration during this period came largely from the field of botany rather than geology. Again, following British law, deposits of gold and silver were regarded as belonging to the Sovereign and thus prospecting for these metals was unattractive in early years.

However, traces of gold were reported from 1823 onwards and the occurrence of other metallic minerals was recorded from time to time in the early decades of the 19th Century.

The first metalliferous mines did not open until the 1840s. Silver-lead ores were mined in 1841 near Adelaide in territory subsequently to become South Australia, and copper at Kapunda in the same general area in 1842. In the same decade but farther east in New South Wales the first pig iron was produced from bog iron ore deposits at Mittagong near Sydney, although the enterprise found great difficulty in competing with imported material and eventually ceased operation in the 1860s.

Establishment of the Mineral Industry

It was the discovery of payable alluvial gold near Bathurst, New South Wales, in 1851 that gave impetus to the mineral industry in Australia and, as search and discovery quickly spread to other parts of eastern Australia, the migrants which the gold attracted, the new communities and new access which resulted, and new emphasis on the mineral potential of the young country profoundly influenced the development of Australia from the 1850s onwards.

It was not long before new interest and expertise in prospecting led to the discovery and exploitation of other metals; the start of tin mining near Inverell, New South Wales in 1871 and at Renison Bell Tasmania in 1872 heralded very considerable tin production in eastern Australia, which in fact became the major world source of tin for nearly a decade in the late 70s and early 80s. Copper mining was rejuvenated by discoveries at Cobar, NSW, in the early 70s, and the finding of Mount Morgan in Queensland in 1882 and of Mount Lyell in Tasmania in 1885; although the two latter deposits were first mined for gold they provided large reserves of copper ore toward the close of the century. The mineral industry was further diversified with the discovery of the rich silver, lead, and zinc lodes at Broken Hill, New South Wales, in 1883, which, to the credit of the pioneers of that field, were developed to the stage of local smelting by 1885 and as feed to larger smelters at Port Pirie by 1889.

Up to this time successful mining had been restricted to eastern and southern Australia, despite attempts to discover payable gold in the Kimberley and Pilbara divisions of Western Australia and in areas east of Perth. However, discovery of payable alluvial gold near Coolgardie in 1893 and subsequently of the gold lodes of Kalgoorlie extended profitable mining to the western portion of the continent at a time when the economy in the east badly needed new outlets.

The Lean Years

The mining industry continued to prosper in the early years of the twentieth century, but fortune began to change and a general decline in both production and ore reserves of copper, gold, and tin continued at least until the 1950s, although gold production temporarily revived in the 30s. During the lean years, significant new mineral discoveries were restricted to lead-zinc at Mt Isa in 1923 and scheelite on King Island in 1925. Only silver, lead, and zinc production and exports, based on Broken Hill in New South Wales and on Mt Isa in Queensland, showed general increases in this period; they continued as a solid base for the mineral industry for most of the first half of this century, in which problems of falling domestic production and lack of new major discoveries became more obvious and challenging as timeelapsed.

However, mineral processing in Australia continued and expanded during this period; production of lead bullion and of copper continued, but output of refined lead (pig) substantially increased in the second decade and was joined by refined tin and by significant increases in refined zinc after 1917. Indeed the term "lean years" applies to exploration; discoveries made in the 19th Century offered challenges to the mineral industry in terms of mining and treatment problems, from mining methods and underground water removal to more efficient smelting, mineral separation and recovery. Some of these challenges were answered by technological improvements and innovation during the lean years for exploration and perhaps the most outstanding example concerns the development of differential flotation for the separation of lead and zinc sulphides from Broken Hill ores and, subsequently, the elctrelytic refining of zinc sulphides to pure metal, in the early part of the 20th Century.

Moreover, early years of the twentieth century were noteworthy for the establishment of the Australian steel industry, which made its way stubbornly against competing imports. Pig iron production, beginning at

Lithgow, New South Wales, in 1875 and based on local coal supplies, provided the base for the first production of steel by open hearth in 1900, but although some production of steel continued at Lithgow until 1932, distance from iron ore supplies and from the coast prevented Lithgow from becoming the centre for expanded steel production. Detailed planning eventually led to the establishment by Broken Hill Co Pty Ltd . of steel works on the coast at Newcastle, New South Wales, in 1915 and, although faced with problems in both the 1920s and the 1930s, steel making was firmly established and expanded. Another enterprise, G. & C. Hoskins, eventually transferred steel making from Lithgow to the coast near Wollongong in 1928, but subsequent trouble in the depression in the early 1930s led to this project being taken over by Broken Hill Co Pty Ltd in 1932.

In the late 1930s the mineral industry, although well established, played a minor role in the Australian economy. It had been particularly successful in opening up the country, had provided black coal as fuel in all States, had bolstered the economy about the turn of the century, and continued to provide steel and processed metals of lead, zinc, copper, and tin for Australian secondary industry.

The need for new ore reserves of many minerals was the major concern of the industry in the late 1930s and early 1940s, and the embargo placed on the export of iron ore in 1938, when reserves of high grade ore were believed to be no more than 260 million tonnes, was a reaction of the Commonwealth Government to this concern.

The Boom Years

It is therefore all the more remarkable that within the next decade, in fact in 1949, began a series of ore discoveries which, at least until 1972, continued to far exceed any previous mining boom in Australia.

The reasons for this spectacular upsurge in exploration and development in Australia are many and complex, but most are concerned either with incentives for exploration and development, including higher metal prices, or with the tools by which they can be accomplished. The combination of mineral potential in Australia (particularly in the extensive areas of Precambrian rocks which have provided the bulk of the world's metals), political stability, and Governmental assistance for exploration and mining attracted both domestic and foreign companies to Australian fields. The general policy of Government of providing basic scientific information, and an encouraging climate for mineral exploration, but leaving private enterprise comparatively free to search, discover, and develop, paid off handsomely.

It is interesting to note how technological progress has changed the pattern of mineral discovery in Australia since the thirties. Before the Second World War the discovery of most mineral deposits owed little to science but much to the keen eye, the luck, or the curiosity of prospectors, boundary riders, and other amateurs. Since the last war, although prospectors and others still make discoveries, the emphasis has shifted to the scientific exploration team.

The mineral industry has resumed its old role of opening up the country with railway lines, roads, ports, and townships, has added oil and natural gas to Australian fuel supplies, and provided processed aluminium and nickel for Australian industry. The long list of significant mineral insufficiencies of the late thirties has been spectacularly reduced to sulphur, asbestos, and industrial diamonds; indeed future supplies of phosphate rock are assured from deposits in Queensland, and recent development of asbestos in New South Wales has significantly reduced our reliance on imported asbestos.

But perhaps the most notable changes brought about by the upsurge of the mineral industry concern overseas funds and the Australian economy as a whole. The value of mineral exports has risen from $69 million in 1950 to $2 406 million in 1974, to provide currently about 30% of Australia's overseas earnings and to replace wool since 1968 as Australia's largest export earning group. The mineral industry produced in 1965 what was probably the first favourable balance of overseas mineral trade this century; this favourable balance has grown from $5 million in 1965 to $1 826 million in 1974 and will undoubtedly continue to increase in the decade ahead.

Moreover, the rise of the mineral industry was timely, happening at a time when wool and most other rural industries were in difficulties, and doubtless saving Australia from currency devaluation and import restrictions in the late sixties. Reserves of iron ore, black coal, and bauxite, which support about 58% of Australian mineral exports, are very large and, combined with long term contracts and rising demand for minerals throughout the world, promise continued major production and export.

However, upsurge of the mineral industry since the Second World War brought problems as well as achievements. The cost of exploration and development far exceeded the funds available in a country with a population of 12-13 million; overseas funds were sought and accepted in terms of risk capital for exploration and investment in mining operations with inevitable erosion of Australian equity in both petrolem and mining industries. Moreover, since ore reserves are wasting assets a continued flow of risk capital is required in the future to provide more reserves, particularly of crude oil if Australia's 70% self-sufficiency in 1974 is to last.

Australia has so far been to a large extent shielded from the world crude oil crisis by the level and prices of domestic supplies, but likely depletion rates already emphasise the fact that, considering the lead time involved in discovery and development of petroleum resources, the value of crude oil imports are bound to rise significantly at least during the remainder of this decade.

Inflation in Australia is currently increasing the cost of exploration, development and production, reducing profitability, increasing cut-off grades and discouraging new developments, particularly where real world metal prices, such as those for copper and nickel, have not kept pace with inflation. Restraints to mineral development have also been increased by changes in taxation schedules and particularly by the repeal of provision for accelerated depreciation in the mineral industry.

Restricted domestic markets for processed products, internal costs, and other factors continue to place restraints on domestic mineral processing and thus on the added value achieved by processing. Again the prosperity of the industry, inevitably based on exports, remains heavily dependent on the Japanese economy, which provided markets for 52% of Australian mineral exports in 1974. Indeed the slowing down of the Australian mineral industry in the latter half of 1971, as a result of lower world metal prices and of checks to the economies of USA and Japan in particular, was a salutory reminder of Australia's dependence on world economies and of the need to diversify mineral trade as much as possible.

Moreover, the late sixties brought growing awareness in Australia as elsewhere of environmental problems which inevitably questioned the disturbance of landscape and levels of pollution which accompanied, in varying degrees, the operations of the mining and some other industries - the mining industry has so far taken the brunt of the attack; as a result the mining industry no longer operates with the degree of isolation from the rest of the community that has been evident in previous years.

To these problems has been added in more recent years growing concern about the future availability of non-renewable mineral resources and the need for conservation on a world scale. Doubtless these concerns are timely and salutory, although in many cases exaggerated; they are beyond the purpose of this summary, but they provide some of the evidence to suggest that the early seventies in Australia may well have begun the transition of the mineral industry from the boom years into a fourth stage of development in which enthusiastic search and development gives place to consolidation and to more deliberate development, and in which attempts will be made to better relate the potential and problems of the mineral industry to overall community needs.

IRON AND FERROALLOYS

Australia has for a long time been largely self-sufficient in the production of iron and steel, and exports have acted chiefly as a buffer between domestic production and demand. Some special steels and shapes and some 30% of our ferroalloys are imported.

Iron and Steel: Production of iron ore for iron and steel-making in 1974 was about 97 million tonnes, an increase of 15 percent above the output in 1973. Production of raw steel in Australia, 7.8 million tonnes in 1974, was 1 percent above that in 1973; production of pig iron decreased by 5 percent to 7.3 million tonnes in 1974. Production of steel and pig iron during 1974 were adversely affected by industrial disputes and labour and coal shortages in the early part of the year. Operational difficulties and blast furnace repairs also adversely affected pig iron output. Most of the steel is consumed on the domestic market, exports of crude steel decreased slightly in quantity during 1974 to 767 000 tonnes but increased in value to $86 million as a result of higher prices. Production capacity for pig iron is surplus to domestic needs and exports were valued at $67 million in 1974. There is a substantial trade in rolled and shaped iron and steel products; exports were valued at $284 million in 1974 and imports at $208 million.

Domestic iron and steel making absorbed 11 million tonnes of iron ore in 1974. The main sources were the Middleback Range in SA, Mount Whaleback, Koolyanobbing, and Yampi Sound, WA. A small charcoal-iron plant at Wundowie near Perth which produces special grades of pig, consumed 92 000 tonnes of ore from Koolyanobbing in 1974; 28 000 tonnes of iron ore, mainly magnetite were imported chiefly from Canada and the Philippines in 1974. In addition to the iron ore consumed in Australia, about 84 million tonnes of ore including 9 million tonnes of pellets were exported; this compares with 78 million tonnes of ore including 9 million tonnes of pellets in 1973. Although exports were principally from Western Australia the Northern Territory and Tasmania continued an export trade; exports increased by 13% in tonnage during the year.

Even in the early post-war period reserves of iron ore in Australia were regarded as too low for safety in comparison with our long-term industrial needs, and few foresaw the possibility of major new discoveries. Because of this a complete embargo on the export of iron ore had been maintained for more than twenty years. Since the embargo was eased in 1960 new discoveries have shown that we possess within our shores one of the most important iron provinces in the world, and a major export trade has been established.

To illustrate the spectacular change in our reserves it may be noted that in 1959 the official estimate of demonstrated reserves amounted to only 369 million tonnes. At that time exploratory drilling in several States had raised hopes that intensified search might reveal some worthwhile new deposits. Among the principal prospects at the time were: Savage River, in western Tasmania, where airborne magnetic surveys had shown a belt of intense anomalies extending over a length of several miles; Constance Range in northwest Queensland, where preliminary testing beneath silica-rich ironstone outcrops had shown a marked improvement in quality at depth and some prospect of large tonnages of ore suitable for deep mining methods; and Mt Goldsworthy, near Port Hedland, Western Australia, where drilling had shown a more substantial body than was indicated by outcrop and surface sampling.

Encouraged by these hopes the Commonwealth Government eased the export embargo in 1960, and soon afterwards a series of discoveries in the Pilbara district, east of Onslow, Western Australia, focused attention on an area hardly touched by modern large-scale mineral prospecting. In the space of a little more than a year important deposits were reported from such localities as Deepdale, Robe River, Mt Tom Price, and Mt Newman, all lying in this neglected northwestern part of the State. Recent discoveries in Western Australia include deposits of hematite and of limonite; early development, at Mt Tom Price, Mt Whaleback, Paraburdoo, Mt Goldsworthy and Koolanooka, was based on hematite deposits, but limonite deposits at Robe River now produce pellets and iron ore fines.

Deposits in Western Australia have since been vigorously tested and extremely large tonnages of high-grade ore have been demonstrated. Though the full extent is not yet known, a recent assessment by The Bureau of Mineral Resources has placed reserves in the Hamersley Iron Province alone at around 32 000 million tonnes within total reserves for Australia of 35 000 million tonnes. In other words, since 1959 our known resources have increased some 95-fold at least and all anxiety for adequate domestic supplies has been removed for many years to come.

However, not all the increase in reserves has come from the discovery of new deposits. Metallurgical research aimed at making possible the use of low-grade ores, of which there is an abundance in several States, has also contributed to the changed picture and may have a greater long range effect that is presently realized. As a result of successful research in the BHP laboratories, low-grade jaspilites of the Middleback Range, previously discarded as waste, can now be economically upgraded for use as furnace feed, and the full benefit accruing at this locality, and to other low-grade Australian deposits, has yet to be assessed.

When the export policy was altered, the change was expected to lead to an increase in prospecting with reasonable chances of proving new reserves. The result exceeded the most optimistic expectations, and led to a situation in which the development of an export trade in ore has become the paramount consideration and one which may play an increasing part in the national balance of payments. The first small-scale export began in March 1966 from Geraldton; and after extraordinarily vigorous construction schedules, large-scale exports began from new ports at Dampier and Port Hedland in the later part of that year.

On the industrial side, rapidly expanding iron and steel plants exist at Port Kembla, Newcastle, Whyalla, and Kwinana; and a small State Government-owned charcoal-iron plant functions at Wundowie, Western Australia.

Investment in iron and steel plant has been running at more than a hundred million dollars annually for several years. New major plant items commissioned since 1962 were a ferro-alloy plant at Bell Bay, Tasmania; an electrolytic tinning line, a high speed pickle line, a second hot-roll processing line, a new blast furnace and a basic oxygen steel-making plant at Port Kembla, New South Wales; a basic oxygen steel-making plant and associated rolling mill facilities, as well as a continuous steel casting plant at Newcastle. At Whyalla a second blast furnace and an integrated steel plant opened in 1965, and an iron ore pelletizing plant was commissioned in 1968. At Kwinana, the first stages of an iron and steel complex were constructed, and a cold rolling plant was completed at Unanderra, where a vacuum degassing plant also commenced operations.

World demand for steel which has been depressed since mid 1974 is projected to show an upturn in 1976.

Manganese is one of the key metals in the manufacture of steel, its chief use being as a de-oxidizer and a de-sulphurizer in the plant process; adequate supplies of its ores are an essential for the long range security of the steel industry. Current usage requires about 30 lb of manganese dioxide for every tonne of steel produced. It is also a hardening constituent in many grades of steel; and high-quality manganese dioxide is used in the manufacture of dry cell batteries. In 1974 150 000 tonnes of manganese ore were required by our industries; our self-sufficiency in this mineral for most purposes has only recently been proved.

For many years the known Australian resources of manganese ore were small. Between 1916 and 1927, the steel industry depended upon deposits in New South Wales; as these were worked out, small deposits in South Australia took their place from 1940 to 1944; subsequently Western Australia became the main source. In the 1950s cheap supplies became available from South Africa, and Australian production slumped, but has recovered again to meet the requirements of a developing export trade, mainly to Japan.

As with iron ore, manganese was subject to a long-standing embargo on exports, but this was partly relaxed in 1956 to allow for shipments of a portion of any new discoveries made. This was designed to encourage exploration and resulted in a burst of prospecting activity in northwestern Western Australia, during which many new small deposits were revealed, amounting in all to several million tons. In 1960 a discovery of much greater importance was made by the Bureau of Mineral Resources at Groote Eylandt, in the Gulf of

Carpentaria, where BHP have now established an open cut mine and treatment plant. Shipments of ore from Groote Eylandt have increased to supply most of Bell Bay's ferromanganese requirements, plus an export surplus. This deposit can supply all of Australia's requirements for metallurgical grade ore for a long period to come; however, we have no supplies of battery-grade ore and continue to use imported ore at the rate of about 1 400 tonnes per year.

Australian production of manganese ore in 1974 was about 1.5 million tonnes. Exports exceed 1.2 million tonnes annually, mainly to Japan and European markets. Imports have shown a marked decline from 1965 and were about 500 tonnes of ore in 1974. Australia's production of high carbon ferromanganese now satisfies local demand, but imports of other grades including powder totalled 10 900 tonnes in 1974. Since the cessation of production in the Port Hedland district of Western Australia in 1973, Groote Eylandt is now the only large scale producer of manganese ore.

Molybdenum: Before 1920 substantial quantities of molybdenite were produced in Australia, but for many years production has been small; there was no recorded production in 1967, but small quantities have been produced annually since then; output was 5.5 tonnes in 1974. Imports in 1973 increased to 713 tonnes of ore and concentrates, and 620 tonnes of ferro-molybdenum.

Most of the molybdenite deposits in Australia occur in pipes whose development to any depth is costly. One exception is at Yetholme, New South Wales, where some 800 tonnes of molybdenite lies at shallow depth beneath a comparatively thin overburden. During World War II the Commonwealth sponsored exploration for new deposits, but results were generally not encouraging. Current production comes from Mareeba, Queensland, but a deposit at Mount Mulgine, Western Australia, is under investigation. Possible recovery of molybdenum as a by-product from treatment of scheelite at King Island in the future could supply only a fraction of our demand.

In times of emergency Australia might look to the United States or Chile to supplement any local supplies, but the total requirement is not large enough to create any real difficulty.

Chromium: Chromite, the ore which yields the metal chromium, has two uses in the steel industry: as an ingredient in the production of alloy steel, and as a chemically inert furnace lining. Its other main use is in the manufacture of chemicals. Australian annual consumption of chromite runs at about 12 500 tonnes, all of which is normally imported. In 1974 18 000 tonnes of chromite were imported, mainly from Iran. Imports of ferrochrome, mainly from South Africa, increased to 13 800 tonnes in 1974.

The largest known Australian deposit of chromite is at Coobina, Ophthalmia Range, Western Australia, where reserves are estimated to be 200 000 tonnes. This deposit, however, is in a remote locality far from coast or railhead, and the cost of working it has been so high that production has only taken place intermittently. It was last worked in 1957, when 1312 tonnes were mined. 138 tonnes of chromite were produced from Licola, Victoria, in 1967, and 86 tonnes in 1968, but no production has been recorded in Australia since 1968.

In general, because of cheaper overseas sources, Australia has been an importer of chromium and its alloys and compounds. Chromium metal is not manufactured locally, and although small quantities of high-carbon ferro-chrome were produced at Newcastle until the closure of that plant at end 1974 all requirements are now imported. In time of emergency we could almost certainly revive our own domestic ore production to meet the necessary demand.

Tungsten: Since tungsten became of commercial importance about 1900, Australia has been an important producer of its ores - wolfram and scheelite - but the scale of production has varied in the face of widely fluctuating overseas prices. The greater part of the product has always been exported. Domestic consumption is small and there should be little difficulty in meeting Australian requirements for ore from known resources whenever the need arises, although we do not currently produce metal or alloys.

The principal deposits are in Tasmania and the Northern Territory. Wolfram comes mainly from Avoca, Tasmania, where Aberfoyle and Storey's Creek mines have been the principal producers; and from Mount Carbine in northern Queensland where R.B. Mining Pty Ltd are operating. A major deposit of scheelite exists on King Island, Bass Strait, but fluctuating world prices have made operations irregular and for a time the mine depended upon the receipt of a Government subsidy. A fresh contract has revived operations in recent years, and known reserves have increased sharply from 1.47 to 7 million tonnes, averaging 0.8% tungstic oxide. Efforts by producer countries, supported by Australia, to achieve an international arrangement leading to price stability have not met with success; world prices remained reasonably firm during 1969, improved in 1970, but generally declined in 1971 and 1972. In mid 1974 prices improved and by October had reached £50.00/mtu but started to fall almost immediately and by December 1975 quotations were in the region of £42/mtu.

Australian production in 1974 (expressed as concentrates of 65% WO_3 content) was 2 148 tons, and recent enhanced prospects on King Island promise higher production of scheelite in the future. The total domestic consumption would seldom exceed 100 tons per annum, its main use being in the manufacture of tungsten-carbide tipped tools.

Nickel: Australia's resources in the past have been small and no domestic production was recorded after 1938. All our requirements were imported; the level had been rising in recent years because of the increased demand for special steels and the greater use of nickel anodes for electroplating. Consumption of nickel is estimated to have increased from about 2 900 tonnes in 1966 to 4 800 tonnes in 1974 and imports of nickel products also rose significantly because the domestic industry does not produce fabricated or semi-fabricated nickel products.

The tightening position of world supplies in the 60s led to intensive exploration in Australia, and many important deposits have come to light. At Kambalda, in Western Australia, Western Mining Corporation has now proved reserves estimated at 24 549 000 tonnes of sulphide ore averaging 3.23% nickel, plus 30 million tonnes of silicate and oxidized ores.

The Metals Exploration-Freeport Sulphur partnership developed a small nickel mine at Nepean near Coolgardie. Ore from the mine is sold to WMC and is treated at the Kambalda concentrator. Ore reserves at Nepean are quoted as 0.35 million tonnes averaging 3.70 percent nickel but recent exploration at depth at the project should lead to a substantial increase in reserves.

Drilling by Great Boulder Mines Ltd and North Kalgurli Mines (1912) Ltd at Scotia near Kalgoorlie revealed about 1.2 million tonnes of nickel sulphide ore plus 2.0 million tonnes of 1.41 percent nickel at neighbouring Carr Boyd Rocks. Mining at Scotia commenced in 1970 and is still in progress whereas mining commenced at Carr Boyd Rocks in 1973 and was suspended in June 1975 because of unfavourable economics. The Windarra Nickel Mines project (WMC/Poseidon) at Mt Windarra and South Windarra have ore reserves of 8.1 million tonnes averaging 1.88 percent nickel. Production from Mt Windarra commenced in the last quarter of 1974.

Smaller ore shoots have been discovered in the Widgiemooltha area by Anaconda-CRA, the Selection Trust Group and BHP-International Nickel. Anaconda-CRA started production from their Redross orebody in 1973 and the Selection Trust Group from their Location 3 orebody in early 1975. Metals Exploration-Freeport International have developed a lateritic orebody at Greenvale in Queensland and have constructed a refinery to produce nickel oxide at Yabulu near Townsville. Production at the refinery commenced in December 1974 and when full scale production is reached in 1976 output from the refinery will be 25 000 tonnes/year of nickel oxide. The Selection Trust Group have discovered and proved a very large nickel sulphide deposit at Agnew 350 km north of Kalgoorlie and have formed a joint venture partnership with MIM Holdings to bring the project into production when economically feasible.

In addition to the projects already mentioned there are several large but low grade deposits which at the present time are not economically viable. There is a large lateritic deposit at Wingellina in Western Australia near the northern section of the South Australian border and a large disseminated sulphide deposit at Mt Keith south of Wiluna which are awaiting more favourable economic conditions before development and production can start. Both of these deposits are in isolated areas and difficulties facing companies which may develop the orebodies include the cost of providing water both for human consumption and industrial use, the high cost of providing the necessary infrastructure and of either upgrading present transport systems or providing new systems.

Production of nickel concentrates commenced in June 1967 at Kambalda and output for that year was 2060 tonnes of contained nickel. In 1974 mine production of nickel was 45 930 tonnes and this figure is certain to be exceeded in 1975 as recently developed projects move towards full scale production. Australia is now the third largest producer of nickel in the non-Communist world. In 1974 about 80 percent of the nickel mined was domestically processed to either metallic nickel or high grade nickel matte and this figure will increase for 1975 as all exports of nickel by WMC were either as metallic nickel or nickel matte. The nickel refinery at Kwinana near Fremantle commenced production in 1970 with an output of 15 000 tonnes/year of metallic nickel. Output in 1974 was about 22 000 tonnes/year and WMC has announced plans to increase this figure to 30 000 tonnes/year. A nickel smelter at Hampton near Kalgoorlie was commissioned in 1972 with a capacity of about 18 000 tonnes/year of nickel in matte but this has since been increased to about 40 000 tonnes/year.

BASE METALS

Copper: Australia, which has again become entirely self-sufficient in copper, had an important early history of production which began as early as 1842 in South Australia; during the first half of this century her known deposits were slowly exhausted, no new ones were found, and it looked as though she would become largely dependent upon imports. However, this possibility was dispelled by the confirmation of very large reserves of copper ore, first discovered in 1931, adjacent to the lead-zinc lodes at Mount Isa. Since then other deposits have been found in several parts of the continent, and working mines like Mt Lyell have been shown to have greatly increased reserves. Exploration is continuing and today we can provide not only for our own needs but for a significant export trade as well.

The Australian scene is dominated by Mount Isa, which produced 65% of the total in 1974 and has reserves sufficient to support a high rate of production for over 25 years. Other important centres are Gunpowder, Qld; Mount Lyell, Tas; Cobar, NSW; and Mount Gunson and Kanmantoo, SA.

It is interesting to observe that the full potential of the Mount Isa deposits was not realized until the early 1950s, although copper was mined for emergency purposes from some minor lodes during the war years. After the discovery by drilling of high-grade copper lodes, a major new enterprise got under way in 1953 and output has grown steadily. It fell, following the 1965 industrial upset, to 55 000 tonnes of metal but recovered and expanded after the Mount Isa-Townsville railway line was relaid for heavier traffic. Record levels of production were achieved in each of three consecutive years after 1968 and again in 1973 and 1974.

Australia has two copper refineries - at Port Kembla and at Townsville. A third at Mt Lyell was closed down several years ago. The refinery at Townsville, a wholly owned subsidiary of Mount Isa Mines, with an annual capacity recently expanded to 155 000 tonnes, is by far the larger. It was commissioned in 1959 and refines the whole of the Mount Isa output. In 1974, 82% of the copper in copper concentrates produced in Australia were domestically processed to blister or refined metal; the closure of the Tennant Creek smelter early in 1975 because of technical problems and low copper prices will adversely affect the level of processing in Australia in the near future; the longer term promises a rising level of processing as output from Cobar (refined at Port Kembla) increases and the Tennant Creek smelter is recommissioned.

In 1965, industrial trouble at Mount Isa affected mine production, and 92 000 tonnes of copper were mined in Australia. 1966 saw a rise of 20% to a record level of 111 000 tonnes; but continuation of K57 shaft development at Mount Isa again reduced the Australian output to 92 000 tonnes in 1967, which rose to 111 000 tonnes in 1968 and progressively to 250 000 tonnes in 1974. Apparent consumption of primary copper in 1974 was 87 453 tonnes. The sources of production in 1974 are as follows:

		Tonnes (metal)
Queensland		
Mt Isa	162 745	
Mt Morgan	11 557	
Mammoth Mine	6 140	
Others	-	180 442
New South Wales		
Cobar	9 179	
Broken Hill	3 381	
Others	-	12 560
Tasmania		
Mt Lyell	25 357	
Others	3 728	29 085
Western Australia		3 702
South Australia		
Burra	768	
Kanmantoo	6 949	
Mt Gunson	2 212	9 929
Northern Territory		
(Tennant Creek mines)		13 720
Total		249 438

Lead: Lead and zinc are usually discussed together because nearly all Australia's production is obtained from orebodies containing both metals, which are mined in the same operation. The lead is then separated from the zinc by crushing and concentration.

Since the discovery, in 1883, and the development of the Broken Hill orebody, perhaps the richest in the world, Australia has been a major producer of lead and zinc ores; and her already dominant position was reinforced by the discovery and exploitation of Mount Isa in the years following 1923. It is interesting to note that Australian metal mining began with silver-lead in South Australia in 1841. We have been amongst the world's leading producers of lead for a number of years past and in 1974 with a production of 375 304 tonnes we ranked as the third largest producer in the world behind USA and USSR. Our known resources are sufficient to allow us to continue as a major exporting country for several decades to come.

Mine production of lead has run uniformly high in recent years, after being below capacity in 1970-71, when it was affected by an international arrangement under which a substantial part of Australian production was voluntarily curtailed. Output in 1974 was substantially below capacity mainly because of industrial problems at Broken Hill.

Details of lead in all mine products from the States in 1974 are as follows:

		Tonnes
New South Wales		
All Broken Hill mines	225 063	
Others	2 495	227 558
Queensland		
Mt Isa		128 210
Tasmania		
Read-Rosebery		19 017
Other States		519
Total		375 304

Most of our lead concentrates are smelted in Australia. There are smelters at Mount Isa, Queensland, and Cockle Creek, NSW, which produced 147 224 tonnes of lead bullion in 1974, and a smelter and refinery at Port Pirie, SA, which produced 201 902 tonnes of refined lead. Domestic consumption was 71 818 tonnes (including 32 000 tonnes from scrap). The level of domestic processing of lead concentrates to bullion or to refined lead is extremely high.

Zinc: For a number of years Australia has ranked fourth behind Canada, USA, and USSR as the world's leading producers of zinc ores. In 1969, mine production reached a record 510 000 tonnes and refined zinc output reached 246 000 tonnes. Output in subsequent years was reduced by voluntary cutbacks (1971), industrial problems and lower ore grades. Mine production was 457 059 tonnes in 1974, from which 276 831 tonnes of zinc were refined. Mining operations were adversely affected by industrial problems at Broken Hill and continued problems at the NBHC mine caused by a mine cave-in in late 1973.

Details of 1974 production are as follows:

		Tonnes
New South Wales		
Broken Hill Mines	255 984	
Others	7 265	263 249
Tasmania		
Read-Rosebery		65 311
Queensland		
Mt Isa		119 282
Total		464 358

There are three zinc refineries in Australia - a large electrolytic plant at Risdon, Tasmania, based on hydroelectric power; an Imperial Smelting Process plant at Cockle Creek, NSW, of a type developed within the last decade; and at Port Pirie, an electrolytic refinery which recovers zinc from a slag dump containing zinc derived from the treatment of lead concentrates was commissioned in 1968. The plant has a rated capacity of about 45 000 tonnes of zinc per year.

About 62% of our total zinc concentrates (all from Tasmania, and some from Broken Hill) were treated at these plants in 1974. The remainder of the concentrates from Broken Hill and all those from Mount Isa were exported. In 1974 production of refined zinc was 283 831 tonnes (including 7000 tonnes from secondary sources). Domestic consumption was about 120 631 tonnes of refined zinc, of which 113 631 tonnes was of primary origin.

Tin: From being a country with a considerable export surplus, Australia became partly dependent on imports about 1947; indeed Australia led the world in tin production for nearly a decade around 1883. The revival of several old mining centres radically changed this position and Australia became again a net exporter of tin in 1966.

In 1969 production of tin in concentrates rose to 8308 tonnes, the highest since 1913, and it increased further to 11 997 tonnes by 1972. However, mine production of tin in 1973 was restricted in accordance with export quotas imposed by the International Tin Council during the first three quarters of the year, and fell to 10 801 tonnes. It fell further in 1974, to 10 481 tonnes, because of flooding, relocation of one of the dredges, and closure of an important producer upon exhaustion of its ore reserves. Production of refined tin also reached a peak in 1972, of 7027 tonnes, and fell to 6714 tonnes in 1974. Export quotas were again imposed in April 1975, and total mine production and refined tin production in 1975 are both likely to fall yet again.

Imports in 1974 were 56 tonnes of refined tin and 887 tonnes of tin concentrates; exports were 2519 tonnes of refined tin, and 10 240 tonnes of concentrates containing 4411 tonnes of tin. Estimated consumption of primary refined tin in the same year was 4300 tonnes. Consumption, which had been increasing steadily, was the same in 1974 as in 1973, and fell markedly in 1975.

Tinplate accounts for more than half the domestic consumption of tin. Production of hot-dipped tinplate commenced at Port Kembla in 1957; an electrolytic line was commissioned in 1962 and another in 1973, and the hot-dipped line closed in 1972. Technological advances have resulted in a progressive decrease in the amount of tin consumed per unit area of tinplate produced; tinplate is also susceptible to substitution by other packaging materials.

Associated Tin Smelters operating at Alexandra, NSW, is the only domestic producer of primary refined tin. Annual smelter capacity is rated at 15 000 tonnes of concentrates.

In the past much of the Australian tin production was from alluvial deposits, particularly those inland from Cairns, in the New England and central west regions of New South Wales, and in northeast Tasmania. However, with the discovery of new orebodies in some old lode mining areas, the emphasis has swung from alluvial to lode mining (both underground and open cut). The major producers, at Renison Bell and Mount Cleveland in northwest Tasmania, Ardlethan in central western New South Wales, and Greenbushes in Western Australia, are all lode miners. The major alluvial producers are two dredges inland from Cairns in north Queensland.

Australia is likely to be self-sufficient in tin for many years to come. Nevertheless, rapidly rising costs have made uneconomic parts of some deposits now being worked, and the gap between production and consumption is likely to decrease more rapidly than was forseen even two or three years ago.

Some of the greatest tin producing countries in the world, Malaysia, Thailand, and Indonesia, lie immediately to the north of Australia as our nearest sources of supply; much farther afield lie the Nigerian and Bolivian deposits, but it is very unlikely that we would be unable to supply our own needs in emergency in the foreseeable future.

URANIUM, THORIUM ETC.

Uranium: Australia is not a consumer of uranium, although small quantities of uranium-derived fuels are imported for use in research at the atomic reactor at Lucas Heights near Sydney. A few years ago we passed through a brief but spectacular interlude as a producer of uranium ore and now appear to be on the threshold of becoming a more important producer. The national search for deposits began in 1944 and bore its first fruit in the discovery of Rum Jungle in 1949 and of Mary Kathleen in 1953. Some small deposits were known in South Australia as early as 1906, and others, which were to become useful but minor contributors to the output, were found in the South Alligator River area, NT, in the early 1950s. Treatment plants for the production of uranium oxide were erected at Port Pirie, where for several years rather high-cost material was produced from ores mined at Radium Hill; Rum Jungle, where the plant remained in operation treating stockpiled ores until 1971; Mary Kathleen, which is in the process of being reactivated from a care and maintenance basis; and Moline, NT, which after fulfilling the last part of an overseas contract for uranium was modified to treat Ag-Pb-Zn ores from Mount Evelyn pending resumption of uranium mining.

All these discoveries were made at a time when uranium was in strong demand for military purposes, and when world supplies were still so uncertain that prices had to be arbitrarily established by Governmental agreement. In the event the prices secured by Australia in several of her long-term contracts turned out to be extremely good, and long before the contracts were fulfilled alternative sources overseas were able to supply more cheaply. At the same time dwindling defence needs and the lack of any comparable requirement for peaceful purposes led to a situation in which no market existed for the Australian product once contracts were fulfilled.

Reserves have been sufficient for any likely domestic need. When Mary Kathleen was closed down, the company stated that there were more than 3 million tonnes of commercial grade ore remaining in the reserves, and additional exploration has more than doubled this figure.

On the other hand Rum Jungle mined out both of its known orebodies, and the plant continued to operate on stockpiled ore, and stockpiled the uranium oxide product, in a program that was completed in 1971. Several years ago it was announced that 1625 short tonnes of oxide had been produced during the life of the Rum Jungle plant and that total revenue over the period of operation has been $42 million. Mary Kathleen produced oxides worth $90 million but there has been no production since 1964.

Meanwhile, the easing of the total export embargo, announced by the Commonwealth Government in 1967, stimulated prospecting for new reserves with notable success. New deposits were found in the Westmoreland area, NW Queensland, near Lake Frome and at other localities in South Australia, at Yeelirrie in Western Australia, and of prime importance the substantial deposits at Ranger 1, Nabarlek, Koongarra, and Jabiluka about 230 km east of Darwin, in a major new uranium province in the Northern Territory. Reserves of uranium ore, mineable at prices up to $US10 per lb U_3O_8, were assessed at June 1975 by the AAEC to be 184 000 tonnes U which is about 19% of the world total.

A mill to produce uranium oxide, with an initial capacity of 3300 short tonnes U_3O_8 year, is to be built to treat Ranger 1 ore. The ore will be mined and treated as a joint venture between the Ranger consortium and the Australian Atomic Energy Commission.

The marketing of uranium has faced difficulties in recent years because the demand for nuclear power is developing more slowly than was forecast; however, some overseas contracts have now been signed and demand is quickening with the current concern about energy supplies.

Australia is assured of natural uranium fuel for any likely nuclear power program, but plans for the first nuclear power station at Jervis Bay are currently in abeyance. The bulk of known reserves of uranium in the western world are held in Canada, Australia, USA, and South Africa.

Thorium and Cerium: The main commercial source of thorium, which has been of interest because of its possible nuclear uses, is in the mineral monazite, a by-product of beach sand operations on both the east and west coasts of Australia. Notwithstanding the use of thorium in several United States experimental reactors, large-scale nuclear uses in fast breeder reactors are said to be unlikely until after 1980. However, this situation could conceivably be changed as a result of new technology, or beneficiation and refining advances.

An increasing interest in monazite results from its rare-earth content, particularly of cerium and yttrium. World demand for rare earths increased sharply in 1973 particularly for high strength, low alloy steels used in oil and gas pipelines. In recent years, the pattern of rare earth applications has changed from one based on the use of rare earths as catalysts to one more strongly oriented to metallurgical applications. Estimated percentage and - use applications in 1974 (compared with 1969) are: catalysts 34% (63.0%), metallurgy 44% (6.4%), glass and ceramics 20% (30.0%), TV electronics, nuclear and miscellaneous 2% (0.6%). Cerium is also present in the mineral allanite, large quantities of which are found in the Mary Kathleen uranium deposit.

High-grade monazite concentrates are recovered from beach sands in Western Australia, Queensland, and New South Wales. The monazite recovered in Western Australia is a by-product of ilmenite production, but elsewhere of rutile and zircon production. Development of extensive mineral sands deposits commenced at Eneabba about 270 km north of Perth in 1973, and the area will no doubt prove to be a major world source of monazite. In 1974 production was 3577 tonnes of concentrates containing about 3270 tonnes of monazite, 71% of which came from Western Australia; Australian production amounts to about 35 percent of total world supplies of monazite. All sales were overseas before 1969, but a former uranium plant, purchased from the South Australian Government at Port Pirie, was commissioned in May 1969 to process domestic monazite. In early 1972 an annual throughput of 1300 tonnes of monazite concentrate was achieved at the plant for the production of cerium and lanthanum hydrates, yttrium oxide, thorium sulphate, and tri-sodium phosphate. However, financial and market difficulties forced closure of the plant in mid 1972.

Australia is undoubtedly self-sufficient in these minerals for any foreseeable requirement; alternative sources of supply would be South Africa, Malaya, India, Brazil, and the United States.

Beryllium: Beryllium is a light-weight metal processed mainly from the mineral beryl, good crystalline specimens of which are better known perhaps as semi-precious stones. The metal has become of particular interest since the development of nuclear technology, but its main use is still in alloys of copper, nickel, and aluminium, which it toughens for industrial uses. Domestic demand, if any, is small.

Australian production of beryl began in 1939 and reached a peak in the war years. It fell away soon afterwards and production in 1967 was only 55 tonnes containing some 6.9 tonnes of beryllium oxide. However, the same year saw exports totalling 637 tonnes of beryl, nearly half to Japan, obtained largely from stockpiled material in Western Australia; there has been no subsequent record of exports to Japan. Production fell to 7 tonnes in 1969, but increased to 20 tonnes of BeO in 1973 before falling to 9 tonnes in 1974. Output in 1975 is expected to be less than in the previous year.

Most of the Australian production has come from a mine near Broken Hill, with some from the goldfield district of Western Australia, although current production comes mainly from Western Australia. In times of emergency, particularly if production costs were not the principal consideration, the small scattered deposits already known could most probably produce sufficient for our foreseeable requirements. Main overseas sources are Brazil, and the United States.

Lithium: The main uses of lithium are in the glass, ceramics, and pharmaceutical industries and in the preparation of greases and welding and brazing fluxes; as lithium seems particularly suitable as a battery anode material, and much interest in battery research has been generated in recent years, a significant market could develop in the future. Consumption of lithium products in Australia is not known in detail, but it is quite small and, except for occasional purchases from local production, requirements are usually imported. South Africa dominates the world production scene but Canada and the United States are alternative sources.

Lithium ores have been produced spasmodically since 1905. In 1974 amounts totalling 1.0 tonnes were produced in Western Australia.

Several years ago a mining company undertook drilling tests on lithium prospects near Kalgoorlie and Ravensthorpe, WA, and extensive reserves are said to have been proved. These deposits would seem to ensure Australia's supplies in any future emergency, but marketing difficulties militate against present large-scale production.

OTHER METALS

Aluminium: One of the most rapidly expanding sectors of our mineral industry is that of the production of aluminium and its ores - bauxite, the raw ore; and alumina, a partly processed product. Little more than two decades ago Australia appeared to be seriously deficient in bauxite resources. Although exploration during the war years had shown that there were small domestic reserves, and the decision was reached to establish an aluminium smelting industry at Bell Bay, Tasmania, it was nevertheless believed that the industry would at most time be dependent upon imported ores with local ores held in reserve.

A series of spectacular discoveries was to change this picture completely. They began in 1949 when relatively small deposits of bauxite were found at Marchinbar Island off the coast of Arnhem Land by the Bureau of Mineral Resources; this was followed by a more substantial discovery on the mainland near Gove. Later, in 1956, very large deposits of bauxite were found at Weipa on the Cape York Peninsula by an exploration company; and in 1958 important new sources were recognized at Jarrahdale, in the Darling Ranges close to Perth, where lateritic bauxites had been regarded as too low grade for commercial exploitation. Most recently, in 1965, an announcement was made of the discovery of further large deposits inland from Admiralty Gulf in the Kimberley district of Western Australia. In late 1970 exploration for possible bauxite deposits beneath the Gulf of Carpentaria, offshore from Weipa, was carried out but was unsuccessful, but exploration on land south of the Weipa deposits has indicated seven hundred million tonnes of bauxite, although the grade has not been specified. Production of ore from Weipa, Jarrahdale, and Gove has mounted rapidly and in 1974 reached 20.1 million tonnes. Australian reserves are now known to be very large, at least 5500 million tonnes, and almost certainly the largest of any country in the world.

On the industrial side, developments have also been rapid, and imports of alumina have been relatively low (2748 tonnes in 1974) and used principally for purposes other than aluminium production since the commissioning of the Gladstone alumina refinery in 1967. The Bell Bay plant, owned by Comalco Industries Pty Ltd, has been expanded to a capacity of 95 500 tonnes of metal per year and will be further expanded to 114 500 tonnes annually by late 1977. It is being supplied with alumina from Gladstone derived from bauxite from Weipa, where extensive mining and shipping facilities are installed. An alumina plant at Kwinana, near Fremantle, WA, with a present capacity of some 1.4 million tonnes per annum, is supplying feed to the smelter at Geelong. Alcoa commissioned a second refinery at Pinjarra, WA, in 1972, with an initial capacity of 210 000 tonnes of alumina per year, which was extended to 700 000 tonnes in 1973 and close to 1 million tonnes by early 1975. The Geelong smelter of Alcoa of Australia Ltd came into production with an initial capacity of 20 000 tonnes of metal and has been expanded in stages to reach 91 500 tonnes. Alumina is also being shipped from Kwinana to Japan, the United States and Bahrein.

The CRA - Kaiser group, in partnership with several other major overseas companies, constructed an alumina plant at Gladstone, Qld, with an output of some 600 000 tonnes of alumina per annum; this has since been expanded in stages to 2 000 000 tonnes per annum. Part of this production is used as feed for a smelter at Bluff, New Zealand, completed in 1971 by Comalco in partnership with Showa Denko K.K. and Sumitomo Chemical Company. The

Bell Bay alumina requirement is provided by Gladstone; the bulk of Gladstone's output is sold overseas, but part also goes to Newcastle, where Alcan Australia Ltd established a primary smelter using coal as a source of power in 1969, with an initial production of 30 000 tonnes of metal, which reached 45 000 tonnes per year in 1971.

Early in 1969 an agreement was completed between the Australian Government and Swiss Aluminium and Australian partners for a project at Gove, NT, to produce 1 million tonnes of alumina and up to 2 million tonnes of bauxite for export; initial shipments of bauxite began in June 1971 and the alumina refinery came on stream in June 1972 and reached its rated capacity of 1 million tonnes/year by mid 1973. The current position in Australia therefore is: resources of bauxite of at least 5500 million tonnes and plant capacity for the production of 5.4 million tonnes of alumina and of 232 000 tonnes of aluminium, with further expansions in train or planned. Conditions of over-supply, evident in world markets in late 1971, were countered by cut-backs in the production of both alumina and metal in Australia in 1972; however, markets gradually improved in 1973 and early 1974 and production was again approaching capacity until a situation of oversupply developed on world markets later in that year. In late 1975, output was running at about 91 percent of total installed capacity.

Antimony: Antimony is used principally to impart hardness and stiffness in lead alloys, as an ingredient in type metal, Babbit metal, Britannia metal, pewter, as a flame retardant (oxide), and in the plastics industry.

Domestic production of antimony in antimony concentrates in 1974 was 819 tonnes, nearly all of which was exported. In addition 478 tonnes of antimony from Broken Hill concentrates was recovered in antimony alloys produced at Port Pirie. The Port Pirie refinery produced 8 846 tonnes of antimonial lead containing 1081 tonnes of antimony in 1974, of which 361 tonnes was recovered from scrap.

Exports of antimonial lead alloy in 1974, mainly to Taiwan, New Zealand and Singapore, amounted to 5400 tonnes valued at $2 441 000. No antimony metal was produced in Australia in 1974 and only 10 tonnes were imported; Mainland China was the sole supplier.

Antimony ores have been produced in Australia since the middle of the last century, but most deposits have been worked out. Recently the only significant production has come from a mine in the Hillgrove area in northeastern NSW - in 1972 production was 898 tonnes of antimony in concentrates.

Exploration for antimony greatly increased under the influence of world shortage and record prices in 1969-70, but with the rapid decline in price in 1971 development has been concentrated on higher grade deposits. Australia is already self-sufficient in antimonial lead but requires minor imports of high purity antimony each year.

Titanium: Australia's resources of titanium minerals (rutile and ilmenite) are considerable. Domestic recoverable reserves are put at about 9 million tonnes of rutile and 46 million tonnes of ilmenite.

Australia currently supplies about 95 percent of world output of rutile concentrates and 20-25 percent of world production of ilmenite concentrates.

The traditional uses of rutile have been in the manufacture of welding rods and the production of titanium metal; since the early 1960s, by virtue of the chloride method of processing, rutile has been used in the manufacture of pigment for high-gloss white paint. Ilmenite usage is virtually confined to pigment. However, the commercial application of processes by which ilmenite is up-graded to approach rutile in TiO_2 content (beneficiated ilmenite or synthetic rutile) will provide a feed for either pigment or metal via the chloride process; beneficiated ilmenite is now beginning to complement supplies of natural rutile to a small extent.

The principal Australian production of rutile is from sands on and adjacent to the beaches of the eastern coast. The discovery in 1971 of old shoreline deposits of rutile, zircon, and ilmenite near Eneabba, 270 km north of Perth, promises a major additional supply of rutile. Commercial production of rutile from this source commenced in 1975 and installed capacity for rutile production in the area is expected to be about 150 000 tonnes/year by the end of 1976. On the eastern coast much of the ilmenite which accompanies the rutile and zircon has too high a chromium content to be saleable for pigment and for the most part has been discarded or stockpiled; however, ilmenite from the more northerly deposits tends to have a more acceptable chromium content and could well provide a suitable base for the production of synthetic rutile in that area in the future.

The principal ilmenite industry has been built up along the southwestern coast of Western Australia. The quality of the ilmenite from this source is most satisfactory for the manufacture of titanium white, and as ilmenite is the main heavy mineral constituent of the sands, its recovery forms the basis of the industry. By-products of ilmenite mining are monazite, zircon, and rutile. In mid 1971 Western Titanium Ltd commissioned a commercial beneficiation plant at Capel, WA, and an annual production rate of 40 000 tonnes of beneficiated ilmenite has been achieved. Both rutile and anatase pigments are produced in Australia at Burnie, Tasmania and at Bunbury, WA. Both plants are based on the sulphate process and use ilmenite concentrates produced from the Capel deposits of Western Australia.

Domestic production capacity for TiO_2 pigments is 60 - 70 000 tonnes/year. Ilmenite concentrates are exported from Bunbury, where substantial bulk loading facilities have been brought into operation. Exports of ilmenite, rutile, and zircon from Eneabba have begun through Geraldton and are expected to increase substantially in the late 1970s.

Zirconium: Australian resources of this metal, in the beach sand mineral zircon, are considerable and are almost twice those of rutile. Zircon is produced as a co-product of rutile mining along the east coast and in the Eneabba-Jurien Bay area, WA, and as a by-product of ilmenite mining in the southwest corner of Western Australia. The market for zircon, principally required for foundries in the form of moulds, facings and cores, and for refractories and ceramics faced oversupply in 1970 but became firm in 1973; as temporary assistance to the industry, the Commonwealth Government early in 1971 supported a stockpiling scheme initiated by industry by controlling the minimum price of zircon in export contracts. The position of oversupply quickly changed to one of short supply, and in 1973 Australia exported a record 431 000 tonnes of zircon concentrates. However, a position of potential oversupply again developed in 1975 and Government re-introduced a minimum price for zircon exports albeit almost five times as high as that in 1971.

Australia's reserves of beach sands make her self-sufficient in these minerals, and particularly in ilmenite, at least to the turn of the century.

Cobalt and Cadmium: Both these metals are by-products in our lead-zinc industry and cobalt is now a by-product in the production of nickel. They have a variety of uses which include (for cobalt) high-temperature alloys, high-speed steels, and magnetic materials, and (for cadmium) electroplating, bearing metals, alloys, solders, and pigments.

In 1974, mine production of cobalt totalled 1078 tonnes, of which 100 tonnes were contained in zinc concentrates from Broken Hill, NSW, 777 tonnes in nickel concentrates produced in Western Australia and 201 tonnes in lateritic nickel ore mined at Greenvale in Queensland; however, only a small proportion is recovered in Australia. The zinc refinery at Risdon, Tasmania, which continues to be the major supplier of cobalt for Australian industry, produced 30 tonnes of cobalt oxide (21 tonnes of cobalt) from zinc concentrates in 1974 - about a fifth of Australian requirements. A nickel-cobalt sulphide product is obtained from the nickel refinery in Perth as a by-product and additional cobalt-bearing products are produced by the nickel smelter at Kalgoorlie and from the new nickel refinery near Townsville; but these products will be exported rather than further refined in Australia in the immediate future. These by-products would make Australia self-sufficient in cobalt if suitably refined; in the meantime a large part of our requirements are imported in the form of metal and compounds mainly from Zaire (the world's principal producer) Canada, Morocco, and Zambia. The USA is an alternative source from which imports are also obtained.

Cadmium is an important metal in alloys for high-pressure bearings which have a low expansion coefficient, and has other uses in cadmium plating of steel, nickel-cadmium batteries, in pigments and chemicals, and in fusible alloys for electric fuses and automatic fire extinguishers.

Production of refined cadmium in 1974 was 720 tonnes of metal; 500 tonnes came from Risdon, 196 tonnes from Cockle Creek, and 24 tonnes from Port Pirie. Mount Isa produce a cadmium-thallium sponge which is exported and reported production of 33.4 tonnes of this material in 1974 containing 15.0 tonnes of cadmium. Domestic sales in 1974 were about 165 tonnes and the rest was exported, including cadmium contained in lead-zinc concentrates. Australia is more than self-sufficient in this metal but the United States, Canada, and Japan are alternative sources.

Magnesium and Calcium: These are derived from the similar sources dolomite and limestone, of which Australia has an abundance. Magnesium is well known as a light-weight metal, being only 2/3 of the weight of aluminium. Suitably alloyed to increase its strength, it has been used increasingly in the aircraft and allied industries. Calcium is a soft metal, of little use on its own, but effective as a hardener of lead. Neither metal is produced in Australia, although magnesium was smelted in limited amounts at Newcastle during the war. Australian resources for production are more than ample.

Gold: Annual production, once steady at above 1 million ounces (32 150 kg) has been falling slowly for a number of years. In 1970, reflecting the difficulties confronting the gold mining industry, production fell to 17 600 kg. In 1974 41 percent of domestic gold production came from gold mines in Western Australia, with a very small contribution from gold mines in Victoria. The remainder (59% of production) came from base-metal mines, principally copper mines, in the Northern Territory, Queensland, Tasmania, and New South Wales, where gold is a valuable by-product. However, rising gold prices in 1971 and 1972 reversed the trend and production rose to 19 000 kg in 1971 and to 23 500 kg in 1972, but production then declined to 15 984 kg in 1974. The major disability suffered by the gold mining industry in recent years was that whereas the price of gold has been fixed for more than 30 years, the cost of production has mounted steadily. In order to keep marginal mines in operation and to maintain existing communities in a number of isolated places, the Commonwealth Government introduced various forms of assistance, including a subsidy on production which was last increased in January 1972. However, subsidy payments cut out when the price exceeds $54 per oz. Gold's main use was that of a dollar earner, with a world price of US$42 per troy oz. However, in 1968 the International Monetary Fund agreed to a two-tier system under which gold might be traded at higher than the official price; in general, this system together with other measures has induced a rising free market for gold which increased notably to about US$60 at the end of 1972, and to US$112 at the end of 1973, promising some rejuvenation of gold mining, but this promise was not fulfilled and production in 1973 fell to 18 936 kg. The two tier system was abandoned in November 1973. Production is expected to decrease slowly in the future. The price of gold was US$195/fine ounce at the end of 1974 but fell in early 1975; however, the end January price in Australia of A$130-135 was encouraging exploration and production but by December 1975 the price had fallen to about $110.

Tantalum-Columbium: Tantalum and columbium (niobium) are metals used in alloying, in high-temperature corrosion-resistant chemical ware, for tipped tool cutting purposes, and in anodes and grids for electronic equipment. Australia was formerly a prominent producer of the ores of these metals (tantalite and columbite), but production has fallen to very low levels. In Western Australia there is commonly a small annual output, mainly as a by-product of tin mining. This amounted to about 108 tonnes of combined concentrates in 1974; and was all exported. There is no domestic demand but if one arose in time of emergency some of the known deposits could most probably be reopened to satisfy the requirement.

Platinum Group Metals: The main uses are in chemical ware, in jewellery, in alloys for electrical purposes, and in the petroleum and glass industries. There has been a small erratic production of platinum and osmiridium for over 70 years but known resources have never amounted to much. Small deposits have been worked in Tasmania and New South Wales but very little production has been recorded from them since 1968; however, interest is resuming in the Adamsfield area of Tasmania. A small amount is commonly recovered annually as a by-product of gold refining at Port Kembla. Platinum is now recovered from nickel co-products produced at the Kwinana nickel refinery. In 1974 production from this source was 240kg of platinum group metals.

Imports in 1973 were valued at $2.4 million and exports were valued at $2.2 million, and 1132 kg were exported. Canada and South Africa are among the world's leading producers and overseas demand was strong. Both producer and free market prices, stable in 1969, have since declined as a result of current world oversupply; but future increased demand in the control of air pollution from motor vehicles should again stabilize the situation.

Selenium and Tellurium: Selenium is used in small quantities in the electronic, chemical, glass, and metallurgical industries but is being replaced in some of its uses with the cheaper materials silicon and germanium. There is some production from tankhouse slimes in the electrolytic copper refinery at Port Kembla, but no statistics are available. Peko Wallsend Ltd produces concentrates containing gold bismuth, copper, silver and selenium at the Juno and Warrego mines Tennant Creek; output for 1974 was 2671 tonnes of concentrate containing 29 000 kg of selenium compared with 2083 tonnes of concentrate containing 18 400 kg of selenium in the previous year. Domestic consumption is not large. Leading overseas producers are USA, Canada and Japan.

Tellurium, a by-product of copper and lead refining, and a notable constituent of the gold ores from Kalgoorlie, is used in metal alloys, in ceramics and rubber manufacturing, and in the military and space industries. Australian consumption is small; recovery, which takes place only periodically from tankhouse slimes at Port Kembla, has not been recorded since 1964.

Bismuth: There has commonly been a small annual production of concentrates of bismuth as a by-product of tin and tungsten concentrates from the Northern Territory and Western Australia. In 1967, the Juno gold mine at Tennant Creek recorded the first production since 1962. Production in 1972 was 360 tonnes of bismuth contained in 1490 tonnes of concentrates produced at Tennant Creek. In 1974 output rose to a record 1170 tonnes more than double the level in the previous year. The bismuth occurs with copper and gold and much of the bismuth reports in copper bismuth flue dust, a by-product of copper smelting. With the closure of the Tennant Creek smelter early in 1975, bismuth - copper concentrates are being stockpiled for further treatment; bismuth - gold concentrates are exported. Research is continuing into methods of processing bismuth concentrates to bismuth bullion containing about 90 percent bismuth metal. Imports of bismuth metal in the period 1970-74 have ranged between 12 000 and 22 000 kilograms. Present uses of bismuth are for low melting point alloys and for the production of salts used in the pharmaceutical and chemical industries. Chief sources are the United Kingdom, Germany and Japan.

Mercury: Australian reserves are negligible, but mercury was produced early in 1967 for the first time since 1945. In 1974 71 kg were recovered as a by-product from the treatment of Rosebery ores at Risdon. Because of pollution fears consumption of mercury declined in 1974; 47 702 kilograms were imported from China, Spain, Philippines and USSR. World production during 1974 was some 9.0 million kg.

Silver: All Australian silver is won as a by-product from mining other metals, more particularly lead and zinc. Mine production in 1974 was 669 954 kg most of which came from the lead-zinc industry. Silver refined in Australia in 1974 was 256 475 kg and almost all the rest of the silver produced was exported in base-metal concentrates, or lead bullion.

<u>Vanadium</u>: This metal, used in both ferrous and non-ferrous alloys, and in the chemical industry, is a common constituent of minerals but is rare in economic deposits. None has been produced in Australia and local consumption is negligible, but recent exploration has indicated possible economic hard-rock deposits in Western Australia and potential supplies as a by-product of petroleum recovery from oil shales in northwestern Queensland. Sources of supply, if required, would be the United States, South Africa, Finland, and Southwest Africa. Western world production in 1974 was about 20 000 tonnes.

<u>Indium</u>: Another alloy metal not commonly found in economic deposits but derived mainly from flue dust in lead and zinc smelters. Australia's consumption is negligible and there is no production or known reserves. It can be obtained from Canada, the United States, Belgium, West Germany, or Japan.

NON-METALS

<u>Abrasives</u>: Australia is deficient in resources of natural hard abrasives, such as diamond, used in many industrial cutting processes; and in corundum and emery. Production of all these is negligible. Small amounts of industrial diamonds were once obtained as a by-product of gold dredging in the Macquarie River, New South Wales, but today the total domestic requirement is imported; imports exceeded 1 million metric carats in 1973 but a considerable amount was re-exported. The Republic of Zaire is the world's major producer, followed by the USSR and other African countries. Some interest has been expressed from time to time in the possibility of diamond deposits in Australia; at present at least one company is active in Western Australia - but so far without discovery. Corundum and emery have been mined on a small scale in Western Australia but there is now no domestic production, and imports commonly amount to about 1300 tonnes, mainly for use

in optical polishing. Rhodesia is the world's leading producer of corundum followed by the USSR and South Africa. Turkey is easily the largest producer of emery.

Part of our requirement of garnet is normally obtained as a by-product of mining beach sands along the eastern coast: imports, almost exclusively from USA, fulfil the remainder of our requirements. Sales of garnet concentrates totalled 83 tonnes in 1974.

Soft abrasives such as diatomite and ground feldspar are produced in Australia in the quantities required, and production could be expanded at will.

Arsenic: Used in insecticides, sheep dips, weed killers, wood preservatives, and in glasses and enamels, arsenic is now all imported (1127 tonnes in 1973). A considerable amount was at one time obtained as a by-product from gold mining at Wiluna, WA, and a number of other domestic sources are known but are not economically exploitable under present conditions. Arsenic is mainly recovered as a by-product of copper and gold mining and the principle world producers are Sweden, Mexico, and France.

Asbestos: Australia has large resources of blue asbestos (crocidolite) in the Hamersley Range, WA but few known deposits of amosite or of white asbestos (chrysotile). However, a chrysotile deposit at Woodsreef near Barraba, NSW, which contains reported reserves of about 11 million tonnes fibre-bearing rock, has recently been developed and came into production in January 1972; output in 1974 was about 35 000 tonnes of fibre (exports were about 21 000 tonnes) and production is expected to rise in the years ahead. The product is dominantly short fibre and although this satisfies local demand and provides exports to Japan, imports of longer fibre chrysotile and of amosite asbestos will remain significant. Imports in 1974 were about 35 000 tonnes of chrysotile, 8000 tonnes of amosite, and

12 000 of other varieties, mainly chrysotile fines. Another deposit at Baryulgil, NSW, which has been exploited for some years, produced about 500 tonnes in 1974.

Because of its fineness, strength, flexibility and suitability for spinning fibre, white asbestos is the most valuable variety. Blue asbestos, which lacks many of the desirable properties of the white, but is stronger and more resistant to chemical action, continues to be used in some parts of the world in the manufacture of asbestos cement products such as building sheets, pipes, guttering, etc. Extensive deposits near Wittenoom, WA were worked till 1966, producing 13 000 tonnes in that year mainly for export, but production has since ceased because of rising costs.

Canada and South Africa are the main sources of supply for imported white asbestos. South Africa is also a source of amosite.

Barite: Australia has adequate resources of barite, the principal use of which is in oil drilling muds, and to a lesser extent in paints, chemicals and paper manufacture. Production can probably be increased to meet any future domestic requirement, but in recent years it has fluctuated widely because of the varying demand by the oil drilling industry. Since 1967, there has been a steady demand by secondary industry and production increased to about 45 000 tonnes in 1970, mainly due to an increased demand for drilling muds in off-shore drilling and to increased export sales. Production in 1971 reached a peak of 54 000 tonnes although exports fell to 16 000 tonnes, reflecting a decline in oil-drilling activity. Subsequently production fell to 26 000 tonnes in 1972 with suspension of output from the Northern Territory to 10 000 tonnes in 1973, and 7000 tonnes in 1974. Imports in 1974 totalled 5270 tonnes and exports 1808 tonnes; apparent consumption was about 11 000 tonnes. Imports of barium chemicals in 1973-74 totalled 4001 tonnes and were valued at $501 000.

Fluorspar: This mineral is essential to the aluminium, steel, chemical, glass and ceramics industries. Consumption is mainly by way of fluorine-bearing chemicals particularly synthetic cryolite and aluminium fluoride which are used in aluminium metal production. In the chemical industry fluorspar is used in the manufacture of hydrofluoric acid. Fluorspar as such is used as a flux in steel and aluminium production and in foundries, in glass manufacture (as an opacifier, flux and refining agent), in enamels for coating metal ware, in the fibreglass industry and in welding electrode coatings.

In previous years, as now, production has been inhibited by ready availability of high quality material from overseas at low prices. Northwest Queensland has contributed most (about 32 000 tonnes) to domestic output but production from there ceased in 1959; regular production from New South Wales ceased before World War 2. However, some production began at Walwa in Victoria in 1970 (1280 tonnes) with reduced production of 466 tonnes in 1971 which increased again to 880 tonnes in 1972 and 1569 tonnes in 1973. However the mine closed down early in 1974, for economic reasons, after production of another 238 tonnes. Imports increased steadily to 32 000 tonnes in 1971, but decreased to 28 000 tonnes in 1972 and to 24 000 tonnes in 1973; imports in 1974 of 29 000 tonnes were valued at $1.33 million. South Africa, Brazil and Thailand were the main sources of imports in 1974. Mexico, Spain and France are also important world producers. Increasing Australian and world demand for fluorspar has induced prospecting activity in most Australian states; promising prospects have been identified in Central Australia, the Kimberleys in WA and north Queensland, and it is hoped that additional production for both domestic demand and export will eventually result.

Bentonite and Fuller's Earth: The demand for bentonite has risen sharply since 1967 because of increased need for drilling mud, in iron ore pelletizing, and the steady demands of foundries. The rise has been met by expanded imports. An important use continues to be as a bonding agent for moulding sands. Local production of bentonite in 1974 was from Queensland (234 tonnes) and Western Australia (328 tonnes), and imports totalled 85 363 tonnes; 78 tonnes of fullers earth was produced in 1974, compared with 30 tonnes in 1973. In recent years, during regional geological mapping, extensive seams of bentonitic clays were discovered in the Carnarvon Gorge in Queensland and a great deal of testing has been going on to decide their economic worth. Deposits of bentonite in other States are also being tested and it is possible that Australian production may rise substantially in the future, although domestic freight rates present current restraints to exploration of new deposits. The United States and Italy are the main world producers of high quality bentonites, which are in heavy demand for drilling muds.

Diatomite: There are many small deposits of diatomite in Australia, which consumes some 20 000 tonnes annually. Production has been almost continuous since 1896, and amounted to 7438 tonnes in 1974, the shortfall being met from imports. Diatomite is extensively used in filtration processes in the manufacture of foods and beverages, as an insulating medium in furnaces and boilers, and as a light-weight filler for paints, varnishes, and synthetic plastics. The Australian product is not entirely suitable for filtering processes and 13 318 tonnes were imported, mainly from USA, in 1974. Resources for other purposes are adequate. The Broken Hill Proprietary Company Ltd is investigating the possibility of developing, in association with Mallina Mining and Exploration N.L., diatomaceous earth deposits near Dongara, Western Australia.

Felspar: Uses are mainly in the glass and ceramics industries and as an abrasive. Australian resources are large and more than enough for any likely requirement. Present centres of production are Londonderry, Mukinbudin and Rothsay, WA, Broken Hill, NSW, for the potash varieties; and the Olary District, SA, for the potash-soda varieties. Production in 1974 was 4145 tonnes. This could be expanded almost at will, but consumption has declined owing to the greater suitability of nepheline syenite for some applications.

Graphite: This mineral has extensive uses as a lubricant, and is employed in many manufacturing processes, for moulding, for graphite crucibles, and in lead pencils. Local production is small and so far no high-grade deposits have been discovered in Australia, although possible resources have not been fully investigated. All our requirements are met by imports, which amounted to some 1940 tonnes in 1974 mainly from China, Korea, and Sri Lanka.

Gypsum: Australia's resources are very large indeed, known reserves being in excess of 760 million tons with the probability of a great deal more. The deposits are associated with salt lakes, and occur in the drier parts of South Australia, Victoria, New South Wales, and Western Australia. The chief use is in the manufacture of plaster, cement, and products such as building boards. In 1974 production amounted to 1 068 852 tonnes, of which 303 167 tonnes were exported.

Limestone, Dolomite and Magnesite: These have been referred to earlier in connection with metals magnesium and calcium. Resources are very large and production could be increased indefinitely. In 1974 limestone production was 11.0 million tonnes and dolomite production was 409 000 tonnes. Magnesite production was 19 300 tonnes.

Mica: Although Australia's resources are probably large, her production, in the face of cheap overseas supplies, is minor. Domestic production of mica in 1974, the first since 1961, amounted to 34 tonnes all from Yellowdine, WA.

While the Commonwealth Mica Pool operated, during and after the war years, a series of small mines in the Harts Range in the Northern Territory produced most of our requirement. With the winding up of the Mica Pool in 1960, the market disappeared. Imports in 1974 amounted to about 1111 tonnes mainly from India, South Africa, and China. In the event of emergency Brazil, Argentine, and Malagasy are possible sources, but Australia's own domestic industry could probably be revived to meet her requirements.

Pigments and Ochres: The term is here used to mean natural earth pigments such as the iron oxides, stained clays, and slate powder which are used to give colour or body to paints, plaster, cements, linoleum, and rubber. A number of small deposits have been worked over the years and Australia undoubtedly has large resources of the iron oxide variety. Some of these are at Wilgie Mia and Weld Range, WA; Rumbalara, NT; Dubbo and Glen Innes, NSW; and the Ulverston-Penguin area of northwest Tasmania. Domestic consumption is very small and there was no production in 1974. Some 1000 tonnes were imported in 1974-75.

Quartz Crystal - Silica: Australia is self-sufficient in various forms of silica used in glass making, foundry sands, refractory bricks, etc., but there has always been an acute Australian shortage of high quality quartz crystal, which has piezo-electric properties that are extremely useful for stabilizing frequencies in radio communications. Quartz crystal is also used in optical instruments. A wide search made by Government agencies during the war failed to disclose any substantial deposits, and an intermittent search by industry in the years since has met with little success. Since 1952 when production was recorded from an occurrence near Glen Innes, the only recorded production of quartz crystal has been from Mukinbudin, WA. A production of 70 tonnes of quartz crystal was recorded from this locality in 1974. Imports of quartzite and natural quartz amounted to 846 tonnes in 1973-74. Recent developments overseas in synthesizing quartz crystal have eased pressure on the need to discover indigenous sources. Some 500 000 tonnes of high-grade silica sand were exported to Japan in 1974, mainly from deposits near Cape Flattery, North Queensland, and also from deposits near Perth, WA.

Sillimanite and Kyanite: These minerals are consumed chiefly in the manufacture of high-alumina refractory linings used in furnaces. Deposits of sillimanite are known in several parts of Australia, mostly in remote localities, and are being worked in NSW and SA. Production had been increasing throughout the 1950s and early 1960s to meet increasing demands from industry, but after a peak of 3500 tonnes in 1963 it steadily declined. Production was 684 tonnes in 1973 and 751 tonnes in 1974 and imports were negligible. Imports of Kyanite have been greater, and in 1974, imports under an item which included Kyanite, sillimanite, andalusite, mullite and dinas earth, totalled 1216 tonnes, mainly from the United States.

India, South Africa, and the United States are major producers but it is likely that Australia could meet her own requirements in any emergency, the present difficulty being essentially economic and mainly cost of transport. The existence of markets, particularly for kyanite in Japan, continues to encourage some exploration.

Salt and Sodium Compounds: Common salt, sodium chloride, can be produced abundantly in certain climatic localities in Australia, either by the evaporation of sea-water or the brines of salt lakes and pans in the drier parts of the continent. Production has been growing in recent years and a worthwhile export trade has been built up. South Australia contributed about 70% of the 900 000 tonnes produced in 1968, but Western Australia produced about half of the total of 1.7 million tonnes in 1969, 75% of the 3.8 million tonnes produced in 1971, 78% of the 3.3 million tonnes produced in 1972, 82% of the 4.1 million tonnes produced in 1973, and 84% of the 4.9 million tonnes produced in 1974 (these statistics exclude Victorian production which is confidential). Western Australian production is almost entirely exported, principally to Japan. Domestic requirements are mainly met by production from South Australia, Victoria and Queensland; production in 1974 from these States was generally adversely affected by weather conditions. Sluggish markets, mainly in Japan, together with an excess of production capacity of the export - oriented producers in W.A., have caused problems of over-supply. However a long-term sustained world demand for petrochemicals will ensure the industry's future. The main production centres in W.A. are Lake Lefroy (Texada Mines Pty Ltd), Dampier (Dampier Salt Ltd), Port Hedland (Leslie Salt Company), Shark Bay (Shark Bay Salt) and Lake Lefroy (Lefroy Salt Pty Ltd).

In recent years several oil wells in the central and northern parts of Australia have revealed large subterranean masses of salt, a type of occurrence well known in oilfields abroad, some of which are also sources of potash. Regional geological mapping has indicated the likely positions of several more. These could offer interesting possibilities if necessity arose but their geographical isolation is such that there seems little likelihood of commercial development at the present time, particularly because investigation so far has not indicated the presence of potash. Sodium compound production does not yet fulfil domestic demand. Imports of sodium salts (which are dominated by sodium hydroxide) in 1974 were valued at $28.1 million dollars.

Sulphur-bearing materials: Consumption of sulphur in Australia, almost all of which is used in sulphuric acid production, steadily increased up to 1967, when a then record 1.99 million mono-tonnes of acid were produced. Production decreased to a low 1.65 million mono-tonnes in 1971 reflecting diminishing demand for fertilizer in times of drought. Acid production recovered to 1.97 million mono-tonnes in 1972 and rose to 2.4 million mono-tonnes in 1973 and 1974. Some 30% of the acid was produced from indigenous sources in 1974 with the remaining 70% coming from imported elemental sulphur.

Commercial deposits of native sulphur and sulphur-bearing ('sour') natural gases are unknown in Australia, but there are large resources of sulphurous materials such as pyrites, base metal sulphides (ores of lead, zinc, etc.), and gypsum. When brimstone was in short supply overseas in the early 1950s the Commonwealth introduced incentives to encourage the use of domestic raw materials for the production of sulphuric acid. These were in the form of bounties on production. Later, when changing circumstances abroad made brimstone plentiful, the Government announced that bounty payments would not be renewed after June 1965; this decision was later reconsidered and the Act was first extended to 1969, thence extended to 1972, when it was allowed to lapse.

Sulphuric acid is currently produced direct from sinter gases from the treatment of lead concentrates at Port Pirie and Cockle Creek; and from zinc concentrates at Cockle Creek and Risdon. Pyrite concentrates are produced as a by-product from copper treatment plants at Mount Lyell and Mount Morgan and from lead-zinc mining at Read-Rosebery; pyrite from Mount Lyell and from Read-Rosebery is railed to an acid plant at Burnie, Tasmania; Mount Morgan pyrite is used in the steel and glass industries. Production of pyrite from Nairne, SA, ceased in 1972. Sulphur is also recovered from oil refinery processes at Altona, Victoria, Hallett's Cove, SA, Clyde, NSW, and Bulwer Island, Qld. Alkylation sludges and hydrogen sulphide from some oil refineries and spent oxide from gas works are also used in sulphur production.

Imports of elemental sulphur were 549 000 tonnes in 1968, but fell to 269 000 tonnes in 1971; with improving rural conditions, imports recovered to 587 000 tonnes in 1973 and increased further to 685 000 tonnes in 1974. Canada and USA were the main source of supply. Non-Communist world production of sulphur in all forms in 1974 was 36.1 million tonnes of which 70% was elemental sulphur. The rising trend of world sulphur demand evident in 1972 strengthened in 1973 and 1974 mainly from the increased requirements of the phosphate fertilizer industry. However, seen in retrospect, the increased demand contained a considerable amount of forward buying and in the first quarter of 1975, as consumers began drawing from their stocks, world trade in brimstone declined markedly.

Vermiculite: This mineral has the unusual property of expanding to many times its original volume when subjected to high temperatures and is used for fire and rot-proofing, as an insulator in electrical and heating equipment, in the manufacture of building plaster, and as a light-weight concrete aggregate. There was no production in Australia between 1956 and 1969, but several deposits are known to exist in Western Australia and 225 tonnes were produced in 1974. A small amount is imported annually (about 3550 tonnes in 1974), usually from South Africa. The United States and South Africa supply almost the entire world production.

Talc, Steatite, and Pyrophyllite: The chief consuming industries are cosmetics, rubber, ceramics, and paint. Small deposits are known in most of the States and, in recent years, South Australia and Western Australia have been the chief producers. Production of talc in 1974 amounted to 69 791 tonnes of which 56 334 tonnes were exported. Imports, mainly of varieties not available domestically, were 1606 tonnes. Production of pyrophyllite from New South Wales totalled 10 046 tonnes. The United States is the leading producer of talc and Japan is the major producer of pyrophyllite, but Australian imports have come from Mainland China, United States, and India, as well as Italy and Norway.

Fertilizers: Gypsum and limestone are not strictly fertilizers but are used in many places for agricultural purposes. They have been dealt with elsewhere in this paper and it need only be said that supplies are abundant. Phosphorite (or phosphate rock) is the main mineral component of manufactured fertilizer.

Phosphate Rock: Phosphate rock is used almost entirely for the manufacture of superphosphate, the production of which was 5.35 million tonnes in 1974. Although South Australia has been the only State to produce phosphate rock since 1965 (when Western Australia also produced 15 tonnes) further statistics will be dominated by production from northwest Queensland; production from BH South's deposits commenced in April 1975 at an initial rate of approximately 18 000 tonnes/month and future development of the domestic fertilizer industry will now be closely linked with continued development of the northwest Queensland deposits.

South Australian production in 1974 was 1484 tonnes; the material is not suitable for superphosphate manufacture and is crushed and applied directly to the soil by local users.

Australia's supplies of phosphate rock are drawn chiefly from Nauru and Gilbert and Ellice Islands (Ocean Island) in the Pacific Ocean and from

Christmas Island in the Indian Ocean. Christmas Island is owned jointly by Australia and New Zealand and phosphate mining is carried out by the Christmas Island Phosphate Commission (CIPC) on behalf of the two Governments. Mining of the Nauru deposits was originally (from 1920 - 30 June 1970) managed by the British Phosphate Commissioners on behalf of the Australian, New Zealand and British Governments although for the latter three years of the period, following effective purchase of the industry by the Nauruans on 1 July 1967, the BPC acted only as managing agents. Subsequent to the formation of the Republic of Nauru on 31 January 1968, the Nauru Phosphate Commission was constituted to manage the industry and, on 1 July 1970, became fully autonomous, controlling all operations of the industry. Production from Ocean Island is still controlled by the BPC. These supplies have been supplemented from other overseas sources, mainly USA and North Africa, when necessary. Total imports of phosphate rock in 1974 of nearly 3.1 million tonnes were 6% higher than in the previous year.

Although the rock from the island sources is very high-grade by world standards, the deposits have a limited life - approximately to the end of this century; the deposits of Ocean Island in the Gilbert and Ellice Islands Group will have been depleted by the end of this decade. Some years ago a widespread search for additional island deposits was made jointly by the Australian and New Zealand Governments, but no discoveries of importance resulted. It was therefore accepted that the chances of finding any new deposits of island phosphate to supplement the existing supplies were small and emphasis was placed on exploration within Australia in late 1964.

Small quantities of phosphate rock have been mined intermittently in Australia for many years and have mostly been used for direct application as a fertilizer. South Australia was the only producer in 1974 with an output of 1484 tonnes. A discovery made near Rum Jungle in 1961 of an unusual type of phosphate deposit in ancient Precambrian rocks has been tested extensively by drilling and pitting. However, the proven reserve is only about 5 million tonnes of which 1 million has a P_2O_5 content ranging from 20-27% and the rest is low grade; the higher grade material is too refractory to constitute an economic source for the manufacture of superphosphate, although the deposit may yet be useful locally as the material, when calcined, is suitable for direct application to the ground. Thin beds of phosphate rock were also found in the Amadeus Basin in the Alice Springs region in 1963 but these proved uneconomic.

In 1964 Commonwealth and State Governments encouraged mineral exploration companies to search for phosphate and this resulted in much increased exploration activity on the Australian continent. About the same time, the Bureau of Mineral Resources arranged for two overseas specialists to assess the phosphate potential of the Australian continent and also possibilities offshore. Recommendations on the continent emphasized eastern Australia and northwest Queensland, and a study by BMR of some of the oil wells which had been drilled in the Georgina Basin indicated abnormally high phosphate content in some formations. Further systematic testing of oil wells by companies led to the delineation of the most favourable formation and this in turn to the discovery of phosphate rock about 50 km south of Duchess in 1966. Continued exploration discovered similar but smaller deposits in the Yelvertoft area about 250 km north of Duchess and additional subsurface deposits in the Barkly Tableland, NT; drilling and assessment have now proved major deposits of phosphate rock in northwest Queensland with reserves of at least 3000 million tonnes averaging about 17% P_2O_5 (with considerable tonnages of 20-22% material) and for the most part capable of beneficiation to produce source material for superphosphate. These deposits assure Australia's supplies of phosphate rock in the long term and should lead to a significant export trade, principally to Asia. Feasibility studies are continuing to determine the long term development of these deposits. In the shorter term BH South has commenced mining 'direct shipping' ore (+ 31% P_2O_5) which is presently being road-hauled to the Duchess rail-siding for railing to Townsville. A 68-km rail-spur from Duchess to the deposits is presently under construction which, when completed in early 1976, will enable the company to increase production to 1 million tonnes/year by mid-1976. A further production-rate increase to 3 million tonnes/year is being planned for the end of 1977.

Potash: All Australian requirements of potash salt are imported. In 1974 Australia imported some 188 000 tonnes of potash fertilizers and potash salts for chemical purposes. The bulk of this came from the United States and Canada.

Commercial deposits of the stratified type (such as are typical of Stassfurt, Germany) have not been discovered so far, though there may be deposits of this type or of others not yet recognized. In particular, evaporite salt deposits could conceivably occur in the beds of some of the numerous dry lakes which are a feature of our arid central areas. Limited scattered boring in some of these lakes has not so far revealed anything of importance. Another possibility may exist in the salt domes discovered during the course of oil drilling.

At Lake Chandler in Western Australia an effort was made at the end of the war to produce commercial potash from an estimated 12 million tons of mud with a content of 60 percent alunite, a potassium-aluminium mineral. The State Government sponsored this attempt, and a plant was erected which was for a while attaining a production rate of 1000 tonnes a year; the operation proved uneconomic and the plant was closed in 1949. In November 1973 Texada Mines Ltd commissioned plant to produce langbeinite ($K_2 Mg_2 (SO_4)_3$) from residual brine liquor of its sodium chloride harvesting operations. Technical problems have interrupted normal production and cumulative output to June 1975 of 9730 tonnes has been stockpiled.

Nitrates: The bulk of Australian requirements for nitrogenous fertilizers and nitrates for industry are produced domestically. As no commercial deposits of nitrates are known to exist in Australia, production is mainly from natural gas, refinery gas, coke-oven gases and imported naphtha.

Consumption of nitrogenous fertilizers has increased markedly since 1966 when the Government introduced the Nitrogenous Fertilizer Subsidy Act which provides a benefit of $78.74/tonne contained N to consumers of nitrogenous fertilizer. The steady increase of consumption is mainly due to the use of nitrogen in new applications especially wheat, other cereals and pasture; although actual quantities of nitrogen consumed in traditional applications to sugar and horticulture have increased, their relative importance is decreasing. The principal N-bearing products applied are urea, anhydrous ammonia, ammonium sulphate and ammonium nitrate. Estimated Australian consumption of N in 1973-74 was 172 300 tonnes. Production statistics of some products are not available for publication but output in 1972-73 of anhydrous ammonia (fertilizer and technical grades) was about 260 000 tonnes, aqua ammonia (fertilizer and technical grades) 70 000 tonnes and ammonium sulphate 121 000 tonnes.

Imports of nitrogenous fertilizers in 1973-74 totalled 15 000 tonnes which contained an estimated 3000 tonnes N.

No commercial deposits of nitrates are known in Australia although the demand for these fertilizers has been increasing significantly both for the cane industry in Queensland and for the wheat industry in Western Australia.

Petroleum: Australia's main mineral deficiency has long been that of indigenous petroleum, the lack of which has compelled her to import an ever growing volume of crude oils and refined products to meet her increasing consumption. In 1974 the value of imports of refinery feedstock and refined products rose to $645 million (crude $420 million) from $196 million (crude $114 million) in 1973 mainly as a result of increased world prices for crude; imports accounted for about 30% of Australian petroleum requirements; indigenous crude oil amounted to about 68% of demand in 1974. The rate of increase in consumption of marketable petroleum products was 3.7% over the previous year but demand is expected to almost double in the next 10 years. The weighted average annual increase in consumption of the same range of products for the five years ended 31 December 1974 was 5.7 percent.

When the first full year of production from Moonie in 1965 the first step was achieved in the national effort to become self-sufficient. In 1967 output from Moonie, Alton, and Barrow Island was 7.6 million barrels; an increase of 124% brought about mainly by Barrow Island coming into production. This represented 5.1% of consumption as compared to 2.7% in 1966. In 1968, Australian indigenous production was 13.8 million barrels, in 1969, 15.8 million barrels, or 8.8% of total petroleum consumption, and 65.1 million barrels in 1970. Production rose rapidly to 112.9 million barrels in 1971 as the Gippsland Shelf fields came on stream.

Since the mid 1950s an Australia-wide search has been going on, with mounting intensity in the 1960s. In 1966 some 101 exploratory wells were drilled in Australia (excluding PNG) (compared with 14 in 1959); in 1967 the number fell to 84; in 1968 the total was 97; in 1969 the number of exploratory wells completed was 99, rose to 119 in 1970 and fell to 72 in 1971, rose to 99 in 1972 and fell to 60 in 1973 and to 51 in 1974 and only expected to reach 24 in 1975.

Part of the reason for the increasing tempo of oil search in Australia in the 60s undoubtedly derived from the Commonwealth's policy of subsidizing private companies' expenditure under a scheme first introduced in 1958, extended to June 1969, and again extended to June 1974. Under this scheme selected operations were at first reimbursed by 50 percent (later reduced to 30 percent) of the cost. The Australian Government did not renew this subsidy scheme after June 1974 but established a Petroleum and Minerals Authority with powers and responsibilities in fields of petroleum and minerals exploration and development. However, the High Court in July 1975 ruled that the Act establishing the Petroleum and Minerals Authority was invalid.

Incentive was further increased by the commercially viable oil and gas discoveries encountered during the years since 1960. These include the gas fields in the Roma area in Queensland now supplying Brisbane with natural gas; the Gidgealpa - Moomba - Big Lake (and the nearby Toolachee) gas fields in South Australia, now supplying Adelaide with natural gas and scheduled to supply Sydney by early 1976 when the Moomba to Sydney gas pipeline is completed; the Gippsland Shelf major gas/oilfields Barracouta and Marlin supplying Melbourne, and the Dongara field in WA now supplying Perth. Other gas fields which have not yet been exploited are Mereenie - Palm Valley in the Northern Territory and fields on the North West Shelf off Western Australia. Gas has also been discovered in the Petrel well, 150 km west of Darwin, and major discoveries of natural gas on the Northwest Shelf off Port Hedland are being appraised and gas from the Tuna field in the Gippsland Basin is to be brought into production in 1977 or 1978.

Crude oil was discovered at Moonie and Alton in Queensland in 1961, and these fields have been producing since 1964. Following this, the Barrow Island oilfield discovery in Western Australia began commercial production in December 1966. The most prolific crude oil discoveries were the Kingfish, and Halibut fields, significant discoveries were made in the Barracouta, Marlin, Mackerel, Tuna, Flounder and Snapper fields in the offshore Gippsland Basin. Commercial production began from Barracouta in late 1969 and was followed by Halibut in 1970 and Kingfish in 1971. The Tuna and Mackerel fields are to be brought into production in 1977 and 1978.

The Commonwealth also contributes to exploration activities in Australia by carrying out, through the Bureau of Mineral Resources, extensive geophysical surveys and geological mapping programs over sedimentary basins.

At the present time exploration permits are held over the surface areas of most of our known sedimentary basins and drilling has been going on in all States and Territories. Of late, the chief focus of interest has turned to the offshore localities, where extensive sedimentary basins exist under the shallow waters of the continental shelves. Drilling offshore is a very much more expensive operation than drilling on land, but the prospects are considered good. The first offshore rig, Glomar III, a drilling ship, was brought to Australia in 1964 at a cost of $2 million. With its first well, Barracouta No. 1, some 50 km from the Gippsland cost of Victoria, it discovered gas and what is now known as the Barracouta field.

The same drilling unit discovered the Marlin gas field shortly afterwards, and the major Kingfish and Halibut oilfields in rapid succession. Glomar III was joined by other offshore drilling units and resulted in further hydrocarbon encounters in the Tuna, Bream, Flounder, Mackerel, Turrum, Cobia and Snapper structures.

Production of crude oil and gas from this prolific area began in 1969, and by the end of 1974 crude oil production was some 61 389 cubic metres per day. Natural gas production from this area also began in 1969 and some 2241 million cubic metres were produced in 1974.

Further offshore drilling units arrived in Australia, and by mid-1969 six mobile units were operating in Australian coastal waters. Three of these units were drilling ships, two were semi-submersible platforms, and one was a jack-up unit. In early 1970 five units were operating, and one was idle. However, only 4 offshore rigs were operating in early 1971, 5 in early 1972, 6 in early 1973, 3 were active at the end of 1974 but only the unit Ocean Digger was in operation at the end of 1975.

In mid-1975, some 295 wells were on production in the Barrow Island field, and total daily crude oil production was around 5800 cubic metres per day. The success of the water flood technique introduced in this field in early 1968 has stimulated production, and it is hoped that this daily rate will be sustained for some time.

The year 1969 saw the completion of three major natural gas pipelines: the 170 km, 30 inch pipeline from Longford to Dandenong commenced delivery to Melbourne and its environs in early 1969, and in the September quarter of 1975 was delivering about 7.8 million cubic metres per day.

Brisbane received its first delivery of natural gas from the Roma area in March 1969 through the 10 $\frac{3}{4}$ inch, 410 km pipeline. Production from this area in the September quarter of 1975 was being sustained at a daily rate of some 0.68 million cubic metres per day.

In late 1969, Adelaide received natural gas through the 22 inch 778 km pipeline from the Gidgealpa - Moomba field. Production through this line was some 3.4 million cubic metres per day in the September quarter of 1975. Natural gas was delivered to the Perth area from the Dongara field in October 1971 which is currently delivering gas at a rate of 2.2 million cubic metres per day. The natural gas line to Sydney from the Cooper Basin fields in South Australia is scheduled to be completed in early 1976, if further delays due to bad weather and industrial troubles can be avoided.

In 1975 indigenous crude oil production from proven fields supplied about 68% of Australia's requirements. However, the crude oils discovered so far are deficient in the heavier distillation fractions required by heavy industry and road and paving construction, and thus important of crudes rich in these fractions must continue, at about 30% of total consumption, until an adequate source is found in Australia. Also since national consumption on average is increasing at about 4% per year, further substantial Australian discoveries are essential in order to maintain or reduce the deficit gap between indigenous production and importation. Should we not be successful in establishing additional petroleum reserves within our own boundaries, it will be necessary to turn our thoughts to other and less convenient source materials for fuel, and to other sources of power such as uranium. Petroleum can be distilled from oil shale, and some attention is now being directed to our shale deposits, particularly those in Queensland; on the other hand our very extensive resources of coal may provide an alternative source if economic methods of synthesis can be developed to suit them. A great deal of attention has been given, for several years, to setting up the research facilities necessary to examine all possibilities connected with making full use of our coal, and a good deal more is being done in this regard than is generally realized. The USA has already advanced far, both in research and applied technology, in this field.

THE ROLE OF GOVERNMENT IN ASSISTING MINERAL EXPLORATION AND DEVELOPMENT

One of the prime needs for any systematic search for minerals by modern methods is for adequate base maps - topographic, geological, and geophysical. It is by provision of these maps, as well as geological and geophysical services generally, that Government makes its main contribution to the search.

It is perhaps not generally known how much effort goes into the mapping program, or how far it has already advanced. The Department of National Resources provides a focus for the various Government agencies engaged in this widespread and important activity. Overall direction of the topographic program is provided by the Department but its activities and those of other Commonwealth mapping agencies are co-ordinated through the National Mapping Council, consisting of the Director of National Mapping (Chairman), the Australian Surveyor General, the Hydrographer RAN, the Director of Military Survey, and representatives of each of the States.

The Commonwealth undertakes all topographic mapping within its own territories and is active in most States; it subsidizes the work of the State agencies to the extent that their work contributes to the Commonwealth program. Commonwealth agencies are the Division of National Mapping (Department of National Resources), which has the primary responsibility, and the Royal Australian Survey Corps (Army), which does a substantial amount of work on the basis of making available those of its resources that are not required solely for military purposes. The aim of the topographical mapping program is to prepare manuscript maps at a scale of 1:100 000 with 20-metre contours. Around the coastal fringe maps will be published at this scale, but for the central portion the scale of publication will be 1:250 000 and the contour interval 50 m. There is a complete interchange of data between the Division and the Survey Corps to minimize cost and two editions will be published, one for military use and one for civilian use. The latter will be distributed by the Department of National Resources. Additionally, quite an appreciable amount of larger scale mapping is produced by State and Territorial authorities for their purposes and by the Army for training purposes.

Both Commonwealth and State agencies undertake regional geological mapping. Programs are agreed upon in consultation between the Bureau of

Mineral Resources and the State Geological Surveys, but the work is necessarily a good deal slower than that of topographical mapping and the time required to complete a similar 1:250 000 coverage of the continent will be several times as long at least. However, over 80% of the continent has been covered since World War II.

Geophysical surveys are largely a Commonwealth responsibility and a great deal of work has been done using airborne equipment. The ultimate aim is to provide nation-wide coverage by gravity, magnetic, radiometric, and seismic measurements. Only two States, South Australia and New South Wales are sufficiently equipped to take a real share in this geophysical program, but the increasing demands of oil exploration have brought into operation a number of private contractors who have carried out a great many useful surveys over parts of the sedimentary basins. Comparable surveys in the field of metalliferous exploration have increased very substantially during recent years.

Other direct contributions to mineral search are made by the Commonwealth in the form of bounties and subsidies. Concession freights by rail are a form of assistance often granted by State Governments.

Another important though indirect form of Commonwealth assistance is through taxation concessions. The object of these is to encourage exploration by making exploration costs recoverable, or to promote development by allowing the recovery of capital outlays either within a relatively short period, or over the estimated life of a mineral deposit; but provisions allowing accelerated depreciation were withdrawn in 1974, and writing off the outlay on the development of a mine was based on mine life only. However, as from 1 January 1976 a new investment allowance has been proposed. This will allow 40% of the cost of new plant and equipment to be written off immediately against income tax.

Particular minerals have been given specifically favourable taxation treatment because it was felt that a national need existed to foster their exploration; and gold mining, for other reasons, has been free of income tax since 1924. Both of these incentives are now under review, but the Industry Assistance Commission, which replaced the Tariff Board, is investigating the need for assistance by the mineral industry.

Government action has also been used to hasten the development of the domestic industry by prohibiting the export of unprocessed raw materials; the beach sand industry, which has been a consistent dollar earner, owes much to this procedure. Initially Australian exports comprised unprocessed sands of low value; but when Government regulations were introduced to prohibit the export of material other than high-grade concentrates, local processing plants quickly came into existence.

Government stockpiling has also been employed occassionally as a means of encouraging production, e.g. monazite and beryl; no current Government stockpiling is in force, although the Commonwealth Government has supported a stockpiling scheme for zircon run by industry.

Policies of export control have been applied with flexibility since 1960 and a policy of permitting partial exports of ores, even when reserves were low, have brought satisfactory results in the fields of iron ore, manganese, and uranium.

<u>Concluding Remarks</u>: The intention of this paper has been to present a picture of Australia's mineral requirements and the manner in which they can be met from her own resources. It need hardly be said that the picture is a favourable one. With a few notable exceptions we can provide for all our needs and, in many cases, an exportable surplus as well. One may confidently expect that with the passage of time most if not all deficiencies will be rectified. It is, in fact, difficult to think that if programs of vigorous exploration keep pace with the growing demands on our mineral deposits, important discoveries will not continue.

TABLE 1. VALUE OF EXPORTS BY INDUSTRIAL GROUPS

	1970/71 Value (f.o.b. $'000)	%	1971/72 Value (f.o.b. $'000)	%	1972/73 Value (f.o.b. $'000)	%	1973/74 Value (f.o.b. $'000)	%	1974/75 Value (f.o.b. $'000)	%
Industrial Groups -										
Agriculture	872,342	20.9	961,800	20.5	831,315	14.0	1,116,704	16.8	2,265,192	27.0
Pastoral -										
Wool	543,827	13.0	582,208	12.4	1,130,467	19.0	1,159,943	17.4	754,123	9.0
Other	553,252	13.2	698,754	14.9	1,128,266	19.0	1,024,186	15.4	628,837	7.5
Dairy and farmyard	107,654	2.6	120,597	2.5	164,445	2.8	165,411	2.5	174,524	2.1
Mines and quarries (other than gold)	1,037,661	24.8	1,100,814	23.5	1,251,386	21.1	1,542,249	23.1	2,254,154	26.9
Fisheries	59,762	1.4	75,634	1.6	75,508	1.3	69,170	1.0	70,989	0.8
Forestry	5,920	0.1	7,367	0.1	9,139	0.2	11,058	0.2	12,072	0.1
Total Primary Produce	3,180,418	76.0	3,547,174	75.5	4,590,526	77.3	5,088,721	76.4	6,159,891	73.5
Manufactures	853,520	20.5	985,815	21.0	1,204,980	20.3	1,384,363	20.8	1,936,699	23.1
Refined petroleum oils	40,080	1.0	57,784	1.2	43,144	0.7	100,721	1.5	157,440	1.9
Unclassified	106,677	2.5	106,348	2.3	98,515	1.7	89,464	1.3	128,489	1.5
Total Australian Produce (excluding gold)	4,182,695	100.0	4,697,121	100.0	5,937,165	100.0	6,663,270	100.0	8,382,518	100.0

SUMMARY OF ORE RESERVES AND MINERAL PROCESSING

A broad summary of ore reserves and capacities for mineral processing in Australia, directed particularly toward the performance of the mineral industry in times of emergency, has been attempted in the accompanying table. Discussions of ore reserves present problems because no realistic estimate of available ore reserves in Australia is yet available for many of the minerals concerned. For a number of reasons, published figures tend to be minimal and ultra-conservative. The Bureau of Mineral Resources is carrying out more realistic assessments of the reserves and has completed and published first assessments of reserves of black coal, of the beach sand minerals, tin, iron ore and antimony; an assessment of reserves of copper is under way and those for other minerals will follow in due course. For the purpose of this report ore reserves have been classified under general categories likely to be significant in terms of industrial mobilization. These categories are based on the expected life of known reserves at current rates of production and are defined as follows:-

Very large - sufficient for more than 100 years ahead
Large - sufficient for 30-100 years ahead
Adequate - sufficient for 15-30 years ahead
Small - sufficient for 5-15 years ahead
Very small - less than 5 years ahead

In some cases, the uncertainty of reserves is indicated.

The table draws attention to a number of cases where mineral reserves are available but with no associated capacity to produce the metal or processed material needed in the manufacturing industry.

TABLE 2 SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

1975

Metal or Mineral	Resources: Distribution	Resources: Reserves	Resources: Current Imports	Mineral Processing: Level of Processing	Mineral Processing: Distribution	Mineral Processing: Current Imports	Possible Disadvantages in Emergency
Ferrous							
Iron ore	Well distributed	Very large	-	Ores and pellets to steels and fabrications	Steel - Well distributed	Ferro alloys-special steels	-
Nickel	West Australia Qld	Very large	-	Concentrates, matte, metal, oxide, sulphide product	WA Qld	Metal & alloys	Metal available but remote from most industrial centres
Chrome	Minor - Victoria	Very small (?)	Bulk of requirements	-	-	Ferro-chrome	Largely dependent on imports
Manganese	Groote Eylandt, NT, WA	Large (metallurgical)	Battery Grade	Ferro-manganese	Tasmania only	Some ferro-manganese and metal	Main reserves NT. No battery grade. No metal capacity.
Tungsten	King Island, Tasmania. Minor-NSW, Qld, NT	Adequate	-	Concentrates	-	Tungsten	Small tungsten carbide capacity (but could be increased)
Molybdenum	Minor-NSW, Qld, Tas	Very small	Bulk of requirements	-	-	Ferro-molybdenum, molybdic trioxide	No domestic capacity of acid and ferro-molybdenum in emergency

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

	Resources			Mineral Processing			
Metal or Mineral	Distribution	Reserves	Current Imports	Level of Processing	Distribution	Current Imports	Possible Disadvantages in Emergency
Non-Ferrous							
Tin	Well distributed. Major - Tasmania	Adequate	-	Concentrates and metal	Metal - Sydney only	Some tinplate	Major deposits off mainland (Tasmania) Only one smelter
Lead	Well distributed - mainly eastern Australia	Large	-	Concentrates, bullion and metal	Metal, NSW, SA	-	-
Zinc	Well distributed - mainly eastern Australia	Large	-	Concentrates, metal	Metal, Tas, NSW, SA	-	-
Copper	Well distributed - mainly eastern Australia	Adequate	-	Concentrates, blister, metal and fabricated	Metal, Qld, & NSW	-	-

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

	Resources			Mineral Processing			
Metal or Mineral	**Distribution**	**Reserves**	**Current Imports**	**Level of Processing**	**Distribution**	**Current Imports**	**Possible Disadvantages in Emergency**
Mineral Sands							
Titanium	E and SW coasts	Adequate	–	Concentrates, upgraded ilmenite, & pigments	Pigment WA & Tas	Any metal required	No metal capacity
Zirconium	E and SW coasts	Adequate	–	Concentrates		–	No metal or oxide capacity
Monazite	E and SW coasts	Adequate	–	Concentrates and minor combined rare earths for polishing	Eastern Aust.	–	Could produce rare earths

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

	Resources			Mineral Processing			
Metal or Mineral	Distribution	Reserves	Current Imports	Level of Processing	Distribution	Current Imports	Possible Disadvantages in Emergency
Light Metals							
Aluminium	Northern and SW Australia	Very large	-	Alumina and metal	Metal, NSW, Vic, Tas	Minor shapes	Major resources N. Aust. Alumina Qld. & WA remote from smelters
Magnesium	Well distributed (magnesite)	Adequate	58% magnesite imported	No metal produced	-	All metal	Metal can be produced as in last war
Nuclear Uranium	Northern Australia, WA & SA	Large	-	U_3O_8 (yellow cake) radioisotopes	Northern Australia Sydney	Radioisotopes	Reserves widespread but current plant in Qld. Others planned
Beryllium	NSW & WA	Small but uncertain	-	No processing	-	Any metal required	No metal capacity
Fuels Coal	Eastern Australia mainly	Very large	Some high quality anthracite	Coke, coal gas, char	Coke-Qld, NSW, SA, Char- Vic, WA	Petroleum Coke	No chemical plants
Petroleum	Well distributed	Inadequate-self-sufficiency 1973 about 70%	About 30% of requirement - crude and refined products	Refinery products	Well distributed	Some refinery products	Major supplies offshore. Import of heavy crudes

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

	Resources			Mineral Processing			
Metal or Mineral	Distribution	Reserves	Current Imports	Level of Processing	Distribution	Current Imports	Possible Disadvantages in Emergency
Chemical Fertilizers							
Phosphorus (Phosphate rock)	NW Qld	Very large	All requirements	-	Super made in all states	Some mixed fertilizers	Dependent on imports until NW Qld deposits exploited - domestic resources only in NW Qld requiring coastal transport
Potassium	WA	Appear adequate	All requirements	-	Fertilizers all states	Some mixed fertilizers	Dependent on imports until product from Lake McLeod used domestically. Deposits remote from factories
Sulphur	(sulphides) well distributed	Elemental nil, sulphide adequate	70% of requirements as elemental	Acid plants	Well distributed	-	Imports needed beyond capacity of domestic sulphide acid plants
Salt	Well distributed	Unlimited	-	Salt, sodium, caustic, chlorine	Well distributed	Some chlorine, 50% caustic required	-

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

	Resources			Mineral Processing			
Metal or Mineral	**Distribution**	**Reserves**	**Current Imports**	**Level of Processing**	**Distribution**	**Current Imports**	**Possible Disadvantages in Emergency**
Minor Metals							
Vanadium	WA Qld (oil shale)	Probably large not developed	-	-	-	All vanadium & composites	No production
Bismuth	Well distributed - mainly NT	Adequate - NT	-	Bismuth in gold & copper concentrates	-	All metal	Small metal capacity
Cobalt	Eastern Australia, WA	Adequate (from nickel ores)	-	Oxide (by product)	Tasmania WA	50% Cobalt plus alloys	No metal or alloy capacity
Mercury	Eastern Australia	Small but uncertain	-	Metal (by-product)	Tasmania	Almost all requirements	Very little normal production - could be increased
Mica	Central and Western Australia	Adequate	-	-	-	All grades	No current operatic but could be produced
Cadmium	Broken Hill Mount Isa Rosebery	Adequate	-	Metal (by-product)	NSW, SA, Tasmania	-	-
Antimony	NSW, Victoria, Western Australia	Large	very small	Metal (by-product), contained in antimonial lead	SA	Metal plus oxides	No metal capacity

MINERAL SUFFICIENCY IN AUSTRALIA