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Mineral Resources of Australia, 1978

by

L.C. Noakes and J. Ward

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Bureau of Mineral Resources

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MINERAL RESOURCES OF AUSTRALIA

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L.C. NOAKES and J. WARD

INTRODUCTION

This paper, designed for Industrial Mobilisation Courses in 1977, 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, therefore though both are of vital importance to the national economy, are not included in this paper.

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 in 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 surpassing 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, shows 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 1976-77 given as 30.1 percent 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 35.0 percent.

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; inflation and increase in domestic costs, relative to those overseas, have eroded our competitiveness and discouraged new developments; 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 50 percent by value of our mineral exports. Indeed the slowing down of the Australian mineral industry since 1975, as a result of lower world metal prices and of checks to the economy of both USA and Japan in particular, serves as a salutary 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 fact 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 1974, 1975, 1976 and 1977 and on evidence to date will continue to rise in 1978. The level of exploration funds, certainly in real terms, declined in 1974 and 1975, and again in 1976; it probably rose slightly in 1977; a high rate of exploration is important if Australia is to be provided with the additional ore deposits required for continued development of the mineral industry in the 1980s, 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 areas. 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 Labour 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 under way at the end of 1975 when however, the Labour Government was replaced by a new Liberal-National Country Party administration. The Labour proposals for revision of the AIDC and for the establishment of the Petroleum and Minerals 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 reorganize The Pipeline Authority.

However, they have adopted guidelines for foreign investment in the Australian mineral industry along the lines of those announced by the previous Labour Government which called for 50 percent Australian equity in the development stage but the percentage is 75% in the case of uranium. However, the current Liberal-National Country Party Government has increased incentives largely in the taxation field and has indicated that their guidelines on the level of Australian equity desired in the development of mining projects will be flexible so that projects of national importance may proceed in cases where available Australian financial support is less than required by the guidelines.

On the other hand, the inevitable growing concern in environmental fields is accompanied by delays and additional costs in some mining development and likely permanent loss of some identified resources particularly in the case of mineral sands. Moreover new emphasis on aboriginal land rights is slowing down mineral exploration and development particularly in the Northern Territory. Despite a Government decision to allow the export of uranium under specified conditions the timing of production from major known resources remains uncertain due to the attitude of industrial unions and to problems associated with aboriginal land rights.

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 1976, 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) Fertiliser minerals;

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

Mineral statistics given are those for 1976, 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, 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. Coal 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.

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 Mount 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 Mount Isa in Queensland, showed general increase 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 time elapsed.

However, mineral processing in Australia continued and expanded during this period; production of lead bullion and of copper continued, but output of refined pig lead 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 electrolytic 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 The Broken Hill Pty Co. 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, steelmaking was firmly established and expanded. Another enterprise, G. & C. Hoskins, eventually transferred steelmaking 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 The Broken Hill Pty Co. 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 lea , 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 Government 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, although 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 \$4044 million in 1976, to provide currently about 38 percent of Australia's overseas earnings and to recently replace the agricultural and pastoral industries as Australia's largest export earners. 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 \$3321 million in 1976 and will undoubtedly continue to increase in the decade ahead.

Moreover, the rise of the minderal industry was timely, happening at a time when wool and most other rural industries were in difficulties, and doubtless saved Australia from currency devaluation and import restrictions in the late sixties. Reserves of iron ore, black coal, and bauxite, which supported about 68 percent 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 not yet

14 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 petroleum 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 73 percent self-sufficiency in oil in 1976 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 have already emphasised the fact that, considering the lead time involved in discovery and development of petroleum resources, the cost of crude oil imports must rise significantly and indeed the Government has set the price of oil discovered from 14 September 1975 at world parity. In 1977 it enacted measures to increase the price of oil discovered before 14 September 1975 in stages to 50 percent of import parity in 1981, with a view to achieving full import parity by 1985.

Inflation in Australia has increased the cost of exploration, development and production, reduced profitability, increased cut-off grades and discouraged 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 were also increased by changes in taxation schedules and particularly by the repeal of provision for accelerated depreciation in the mineral industry although changes in 1976 and 1977 have provided more encouragement.

As has already been pointed out, the world economic recession has added to the industry's problems because of the restricted domestic market and consequent dependence on exports by the industry.

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 salutary, although in many cases exaggerated; they are beyond the purpose of this summary, but they provide some of the evidence to suggest that the 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 1976 was about 93 million tonnes, a decrease of 5 percent below the output in 1975. Production of raw steel in Australia decreased to 7.77 million tonnes in 1976, one percent below that in 1975; production of pig iron decreased by one percent to 7.42 million tonnes in 1976. Although domestic demand remained static, production of steel was maintained early in the year through export sales but orders declined substantially in the latter part of the year.

A high proportion of iron and steel products continued to be exported in 1976; exports of crude steel were 1 534 000 tonnes valued at $162 million. Exports of crude steel plus rolled and shaped iron and steel products were valued at $375 million in 1976 and imports at $176 million. Production capacity for pig iron is surplus to domestic needs and exports were valued at $49 million in 1976.

Domestic iron and steel making absorbed 10.6 million tonnes or iron ore in 1976. The main sources were the Middleback Ranges in SA, Mount Whaleback, Koolyanobbing, and Yampi Sound, WA. A small charcoal-iron plant at Wundowie near Perth, which produces special grades of pig, using charcoal as a reductant, consumed 92 000 tonnes of ore from Koolyanobbing in 1976; 50 700 tonnes of iron oxide, mainly magnetite, were imported chiefly from Canada and the Philippines in 1976 for use as a heavy medium in the coal washing industry. In addition to the iron ore consumed in Australia, about 81 million tonnes of ore including 9 million tonnes of pellets were exported, slightly more than the 80 million tonnes of ore including 9 million tonnes of pellets exported in 1975. Exports were principally from Western Australia; Tasmania continued to export pellets. Although reduced demand has resulted in a fall in the quantity of iron ore exported since 1974 the f.o.b. value of exports has increased to $828 million (589 million in 1974) because of increased prices.

Even in the 1940s and 1950s 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 economic resources in the Hamersley Iron Province alone at around 15 300 million tonnes within total economic resources for Australia of 17 800 million tonnes. In other words, since 1959 our known resources have increased some 48-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, expanding iron and steel plants exist at Port Kembla, Newcastle, Whyalla, and Kwinana; and a small charcoal-iron plant functions at Wundowie, Western Australia.

Investment in iron and steel plant is now running at almost three hundred million dollars annually and has been running at more than a hundred million for several years. New major plant items commissioned since 1962 were a ferro-alloy plant and expansions 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.

Although there were indications early in 1976 of a recovery in demand for steel in major non-communist consuming countries, the resurgence eased somewhat later in the year and demand remained depressed in 1977.

Manganese is one of the key metals in the manufacture of steel its chief use being as a de-oxidiser and a de-sulphuriser 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 1976, 262 000 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 tonnes. 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 1400 tonnes per year. In addition increasing quantities of electrolytic manganese dioxide (1100 tonnes in 1975-76) are being imported from Japan and USA for battery manufacture.

Australian production of manganese ore in 1976 was about 2.2 million tonnes. Exports exceed 1.7 million tonnes annually, mainly to Japan and European markets. Imports other than battery grade ores have shown a marked decline from 1965 and were about 110 tonnes of ore in 1976. Australia's production of high carbon ferromanganese now satisfies local demand, but imports of other grades including powder totalled 4880 tonnes in 1976. 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. No domestic production of Commercial-grade molybdenite concentrates was recorded in 1976. Imports of molybdenum ore and concentrates fell by 53 percent in 1976 to 91 tonnes, imports of ferromolybdenum dropped by 38 percent to 92 tonnes, and imports of molydenum oxide and hydroxide decreased from 31 tonnes in 1974 to less than 1 tonne in 1975; figures are not available for 1976.

Most of the molybdenite deposits in Australia occur in pipes, of which 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. Production from Mareeba, Queensland, is expected to re-start in 1978, and a deposit at Mount Mulgine, Western Australia, is under investigation. Recovery of molybdenum as a by-product from treatment of scheelite at King Island in 1978 could supply part 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.

<u>Chromium</u>: 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 6500 tonnes, all of which is normally imported. In 1976, 3500 tonnes of chromite was imported, mainly from South Africa and the Philippines. Imports of ferrochrome, mainly from South Africa, increased to 6020 tonnes in 1976.

The largest known Australian deposit of chromite is at Coobina, Ophthalmia Range, Western Australia. The only recorded production was between 1952 and 1957 when approximately 14 500 tonnes of ore was produced. Investigations in the 1970s indicate that the deposit, which is variable in grade and structurally complex, cannot support an economic mining operation despite the nearby development of transport and processing facilities for iron ore at Newman. The most recent production of chromite in Australia was 138 tonnes from Licola, Victoria, in 1967, and 86 tonnes in 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 the end of 1974, all requirements are now imported. In time of emergency we could almost certainly revive our domestic ore production to meet the 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 Queensland. 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 Lty Ltd is operating. A major deposit of scheelite exists on King Island, Bass Strait where known reserves have increased from 1.47 to 6.7 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. By the end of 1976, the quotations were close to £90/mtu. On 1 December 1976, quotations in the United Kingdom were changed from sterling to United States dollars. In mid 1977 the quotation was US$187mtu but had declined slightly by the end of 1977.

Australian production in 1976 (expressed as concentrates of 65% WO_3 content) was 3753 tonnes, and recent enhanced prospects on King Island and at RB Mining at Mt Carbine promise higher production of scheelite in the future even if operations are stopped at the high cost mines in the Avoca area. The scheelite produced at King Island contains sufficient MoS_2 to attract a penalty. A plant to produce artificial scheelite is being constructed there, and the resulting by-product MoS_2 will be sold. The total domestic consumption of WO_3 has never exceeded 100 tonnes per annum, its main use being in the manufacture of tungsten-carbide tipped tools.

Nickel: Australia's identified nickel resources in the past have been small and there was no significant domestic production before 1967. All our requirements were imported; the level had been rising 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 900 tonnes in 1950 to a peak of 5000 tonnes in 1973; consumption was only 3600 tonnes in 1976 as a result of the continuing economic recession.

The tightening position of world supplies in the 1960s 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 22 233 000 tonnes of sulphide ore averaging 3.19% nickel and at Ora Banda the company has identified more than 30 million tonnes of lateritic resources considered to be sub-economic at present.

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. Total indicated and inferred reserves at Nepean are quoted as 0.437 million tonnes averaging about 4 percent nickel.

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 1.0 million tonnes of 1.41 percent nickel at neighbouring Carr Boyd Rocks. Mining at Scotia commenced in 1970 and ceased in 1977 whereas mining commenced at Carr Boyd Rocks in 1973 and was suspended in June 1975; recommenced in early 1977 but was suspended again in September 1977. The Windarra Nickel Mines project (WMC/Poseidon) at Mt Windarra and South Windarra had ore reserves of 8.39 million tonnes averaging 1.48 percent nickel at 30 June 1977. 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 at Spargoville 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 reached 20 300 tonnes/year of nickel in oxide and mixed sulphide product in 1976. 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 with a view to bringing the project into production in 1978.

In addition to the projects already mentioned there are several large but low grade deposits which at the present time are not economically viable. The large lateritic deposit at Wingellina in Western Australia near the northern section of the South Australian border and the large disseminated sulphide deposit at Mt Keith, south of Wiluna, require 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 1976 mine production of nickel was 82 532 tonnes. Australia is now the third largest producer of nickel in the non-Communist world. In 1976 about 95 percent of the nickel mined was domestically processed to either metallic nickel, high grade nickel matte or sintered nickel oxide. The nickel refinery at Kwinana near Fremantle commenced production in 1970 with an output of 15 000 tonnes/year of metallic nickel. Output in 1976 was about 22 000 tonnes/year and the plant has the capacity to produce 30 000 tonnes/year. WMC commissioned a nickel smelter at Hampton near Kalgoorlie in 1972 with a capacity of about 18 000 tonnes/year of nickel in matte, but this has since been increased to about 35 000 tonnes/year and plans were announced in 1976 to double the capacity in the next few years.

BASE METALS

<u>Copper</u>: The first recorded production of copper was in the Kapunda field of South Australia in 1842 and at Burra in 1846. In the early years, Australia was one of the world's leading producers, but

during the first half of this century her known deposits were slowly depleted, no new ones were found, and it appeared that she would soon 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. Important discoveries of copper mineralisation have been made recently in Western Australia and South Australia. Exploration is continuing at these and other prospects and for some time Australia can be expected to provide not only for its 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 1976 and has reserves sufficient to support a high rate of production for over 25 years. Other important centres are Mount Lyell, Tas; Cobar, NSW; and Mount Gunson, S.A. Production from the Woodlawn lead-zinc-copper mine in NSW is expected to begin in the latter half of 1978.

It is interesting to observe that the full potential of the Mount Isa deposits was not realised 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 since grown steadily. The Mount Isa-Cloncurry region of Queensland is the most important copper mining province in Australia both historically and on the basis of mine production. Almost 1 million tonnes of copper have been produced since 1884. Most of the copper has been recovered from the Mount Isa mine.

Domestic mine production has been increasing steadily in recent years because of expanded output from the Mount Isa and Mount Lyell mines and the commissioning of several new mines in the late 1960s and early 1970s.

Record levels of production were achieved in each of the three consecutive years after 1968, and again in 1973 and 1974.

Details of copper in all mine products from the States in 1976 are as follows:

		Tonnes (metal)
Queensland		
Mt Isa	140 934	
Mt Morgan	5 337	
Mammoth Mine	9 172	
Others	177	155 620
New South Wales		
Cobar	8 362	
Broken Hill lead-zinc mines (by product)	3 323	
Others	12	11 697
Tasmania		
Mt Lyell	21 245	
Others	4 097	25 342
Western Australia		
Nickel mines (by-product)	4 353	
Whundo	1 673	6 026
South Australia		
Burra	1 581	
Kanmantoo	4 198	
Mt Gunson	8 392	14 171
Northern Territory		
Tennant Creek Mines	2 912	
Others	-	2 912
Total		215 768

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 1976, 84% of the copper in copper concentrates produced in Australia was domestically processed to blister or refined metal. It is expected that the level of domestic processing will rise during the next decade as mine production at Woodlawn and refinery output at Port Kembla increases and the Tennant Creek smelter is recommissioned.

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 silver-lead-zinc 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 1976 with a production of 397 403 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 1976 was below capacity;

increased concentrate output at Mount Isa failed to offset lower production from all Broken Hill mines where cutbacks were introduced because of the continuing weak zinc market.

Details of lead in all mine products from the States in 1976 are as follows:

		Tonnes
New South Wales		
All Broken Hill mines	216 151	
Others	2 117	218 268
Queensland		
Mt Isa		160 734
Tasmania		
Read-Rosebery		18 034
Other States		367
		397 403

Most of our lead concentrates are smelted in Australia. There are smelters at Mount Isa, Queensland, and Cockle Creek, NSW, which produced 160 690 tonnes of lead in lead bullion in 1976, and a smelter and refinery at Port Pirie, SA, which produced 190 850 tonnes of refined lead. Domestic consumption was 75 218 tonnes (including 29 600 tonnes from scrap). Most lead concentrates produced domestically are refined in Australia to bullion or to refined lead.

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. Output in subsequent years was reduced by voluntary cutbacks, industrial problems and lower ore grades. Mine production was 468 586 tonnes in 1976, from which

242 635 tonnes of zinc were refined. Mine production was 6 percent lower than in 1975; several producers cut back production as a result of continuing poor demand both in Australia and overseas.

Details of 1976 production are as follows:

		Tonnes
New South Wales		
Broken Hill Mines	265 763	
Others	9 036	274 799
Tasmania		
Read-Rosebery		62 004
Queensland		
Mt Isa		125 128
Other States		6 655
Total		468 586

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; and at Port Pirie, an electrolytic refinery which recovers zinc from a slag dump 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 60% of our total zinc concentrates (all from Tasmania, and some from Broken Hill and Mount Isa) were treated at these plants in 1976. The remainder of concentrates from Broken Hill and Mount Isa were exported. In 1976, production of refined zinc was 249 635 tonnes (including 7000 tonnes from secondary sources). Domestic consumption partly recovered from the low rate in 1975, to 86 669 tonnes of refined zinc, of which 79 669 tonnes was of primary origin.

<u>Tin</u>: From being a country with a considerable tin 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 reached a peak of 11 997 tonnes in 1972. Production of refined tin also reached a peak in 1972, of 7027 tonnes. The International Tin Council imposed export quotas in April 1975, which remained in force until June 1976. These quotas, together with abnormally low domestic consumption, resulted in a substantial fall in both mine and smelter production in 1975. With the removal of the export quotas, mines returned to full production; mine production in 1976 was 10 611 tonnes of tin-in-concentrates and smelter production was 5603 tonnes of refined tin. With high tin prices and expansion of capacity by some mines, mine production is likely to increase further in 1977; smelter production is likely to be about 5560 tonnes of refined tin.

Imports in 1976 were 32 tonnes of refined tin; exports were 2315 tonnes of refined tin, and 8344 tonnes of concentrates containing 3363 tonnes of tin. Estimated consumption of primary refined tin in the same year was 3646 tonnes. Consumption in 1977 will probably be about the same as this.

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

per unit area of tinplate produced. Tinplate is susceptible to substitution by other packaging materials, but increases in energy costs or costs of raw materials have affected adversely the competitiveness of substitutes such as aluminium and plastics.

Associated Tin Smelters, operating at Alexandria, NSW, is the only domestic producer of primary refined tin. Annual smelter capacity is rated at 15 000 tonnes of concentrates. The increasing proportion of concentrates from lode mining referred to below, means that the output capacity of refined in has been reduced, because concentrates from lode mining have a lower tin content and contain more deleterious impurities than those from alluvial mining. The predominant mine producer, Renison Limited, has announced that it is studying the feasibility of constructing its own smelter.

In the past much of the Australian tin production was from alluvial deposits, particularly those inland from Cairns in north Queensland, 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. Recent high prices have counterbalanced cost increases, but it is not certain how long these prices will prevail. Published reserves in deposits are sufficient for only a few years, although a continuation of the high prices could result in reserves being increased.

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 we may now 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 1954. 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; 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; and Mary Kathleen which commenced operations in 1956 and was placed on care and maintenance in 1963.

All these early 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 Government 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 increased this figure to more than 5 million tonnes at an average grade of 1.2 kg U_3O_8/tonne.

On the other hand the deposits at Rum Jungle were mined out and the plant continued to operate on stockpiled ore, and stockpiled the uranium oxide product, in a program that was completed in 1971. 1625 short tons of U_3O_8 were produced during the life of the Rum Jungle plant and the total revenue over the period of operation was $42 million. Mary Kathleen produced oxides worth $90 million up until 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 extractable at costs up to $US80.kgU, were assessed at June 1977 by the AAEC to be 289 000 tonnes U, which is about 20% of the world known resources extractable at that cost.

The Mary Kathleen mine and mill reopened in 1976 after extensive modifications and 359 tonnes of uranium in yellowcake was produced during the year.

A mill to produce uranium oxide, with an initial capacity of 3300 short tonnes U_3O_8/year, is planned to treat Ranger 1 ore. The Ranger project was the subject of a major environmental enquiry in 1975 and 1976 and the Commission produced its first report on this project in November 1976 and its second and final report in May 1977.

There was a very dramatic increase in demand for uranium in 1975 and 1976, with prices for spot sales increasing from US\$10.50/lb U_3O_8 in 1974 to about \$40/lb U_3O_8 at the end of 1976. The increased prices reflect the concern that there could be a shortage in the mid 1980s, and this has been accentuated by the fact that one company announced that it could not honour its forward fuel supply commitments, and also by doubts about the development of the Australian deposits.

Australia is well endowed with uranium resources which account for about 20% of the total in the western world. The bulk of known reserves of uranium in the western world are in USA, Australia, Canada, and South Africa.

Thorium and Cerium: The main commercial source of thorium, which has been of interest because of its possible nuclear uses, is 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 many years off. Although research on the nuclear application of thorium continues, commercial application of the thorium-uranium fuel cycle in the high-temperature, gas-cooled reactor (HTGR) as an industrial source of high temperature heat seems further away than ever.

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 end-use applications in 1976 (compared with 1969) are: catalysts 38% (63.0%), metallurgy 32% (6.4%), glass and ceramics 28% (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 is now a major world source of monazite. In 1976 Australian production was 5310 tonnes of concentrates containing about 4906 tonnes of monazite, 76% of which came from Western Australia; Australian production amounts to about 45 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, Malaysia, 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 semiprecious 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. There was no production in 1975 or 1976.

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, 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, but no production was recorded in 1975 or 1976.

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: Over the past two decades, one of the most rapidly expanding sectors of our mineral industry has been that of the production of aluminium and its ore, bauxite, 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 times be dependent upon imported ores with local ores held in reserve.

A series of 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 Cape York Peninsula by an exploration company; and in 1958 important new sources were recognised at Jarrahdale in the Darling Ranges close to Perth, where lateritic bauxites had been regarded as too low grade for commercial exploitation. In 1965, an announcement was made of the discovery of further large deposits inland from Admiralty Gulf in the Kimberley district of Western Australia, and in 1973 it was announced that extensive, lower grade deposits lay to the north of these, on Cape Bougainville. Exploration during the early 1970s on land south of the Weipa deposits indicated seven hundred million tonnes of bauxite, although the grade has not been announced. Production of ore from Weipa, Jarrahdale, and Gove has mounted rapidly and in 1976 reached 24 million tonnes. Australian reserves are now known to be very large, at least 6500 million tonnes, and the largest of any country in the world apart from Guinea.

On the industrial side, developments have also been rapid, and imports of alumina have been relatively low (3199 tonnes in 1976) and used principally for purposes other than aluminium production since the commissioning of the Gladstone alumina refinery in 1967. The Bell Bay smelter, owned by Comalco Ltd, was expanded to a capacity of 112 000 tonnes/year of metal; commissioning of the new capacity began in July 1977. Bauxite mining and shipping facilities at Weipa are currently capable of handling over 11 million tonnes/year. An alumina plant at Kwinana, near Fremantle, WA, with a present capacity of some 1.4 million tonnes/year, is supplying feed to the smelter of Alcoa of Australia Ltd at Geelong. Alcoa commissioned a second refinery at Pinjarra, WA, in 1972, with an initial capacity of 250 000 tonnes of alumina per year, which has been expanded in stages to its present capacity of about 2 million tonnes/year. Alcoa intends to build a third refinery at Wagerup, about 120 km south of Perth, WA. Initial capacity will be 200 000 tonnes/year although there is provision for expansion to 2 million tonnes/year. The Geelong smelter came into production in 1963 with an initial capacity of 20 000 tonnes of metal and was expanded in stages to reach 91 500 tonnes by late 1969. Alumina is also being shipped from Kwinana to Japan, the United States and Bahrain.

The CRA - Kaiser group, in partnership with several other major overseas companies, commissioned an alumina plant at Gladstone, Qld, which processes bauxite from Weipa. The plant had an output in 1967 of some 600 000 tonnes/year of alumina; this has since been expanded in stages to 2 400 000 tonnes/year. Part of this production is used as feed for a smelter at Bluff, New Zealand, completed in 1971 by Comalco in partnership with Show 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 goes to Bell Bay and also to Newcastle, where Alcan Australia Ltd established a primary smelter in 1969, using coal as a source of power, with an initial production of 30 000 tonnes of metal, which reached 45 000 tonnes/year in 1971. A $45 million expansion program has commenced, to increase production capacity to 67 900 tonnes/year by late 1979.

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. Operating capacity is about 1.1 million tonnes/year, and this will increase by about 10 percent by 1980, following modifications to the refinery to produce 'sandy' instead of 'floury' alumina. The current position in Australia therefore is: resources of bauxite of at least 6500 million tonnes and plant capacity for the production of 6.9 million tonnes of alumina and of 248 500 tonnes of aluminium, with further expansions in train or planned. After the conditions of over-supply on the Australian and world markets in 1975, there was a marked improvement in demand in 1976, and companies progressively brought back into production capacity rendered idle during a period of cutbacks, and by the end of the year output was running at installed capacity. The three domestic smelters continued to operate at full capacity throughout 1977.

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 (as the oxide), and in the plastics industry.

Domestic production of antimony in antimony concentrates in 1976 was 1350 tonnes, nearly all of which was exported. In addition 542 tonnes of antimony from Broken Hill concentrates was recovered in antimony alloys produced at Port Pirie. An additional 30 tonnes of antimony was contained in retreated railings from the old Costerfield mine dumps. In 1975, the Port Pirie lead refinery produced 10 366 tonnes of antimonial lead and 9598 tonnes of lead sheathing alloy containing 939 tonnes of antimony of which 312 tonnes was recovered from scrap.

Exports of antimonial lead alloy in 1976, mainly to Malaysia, New Zealand, and Taiwan, amounted to 6292 tonnes valued at $2 569 000. No antimony metal was produced in Australia in 1976 and 33 tonnes, valued at $81 000, were imported; Mainland China was the main 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 mines in the Hillgrove area in northeastern NSW - in 1976 production was 1126 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. The Blue Spec antimony-gold mine, 150 km southeast of Port Hedland, WA began production in mid-1976. The mine is expected to produce about

1270 tonnes/year of antimony and 1200 kg/year of gold over a planned mine life of 28 months. However problems were experienced during 1976 and the first half of 1977 and the plant operated well below capacity. 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 10 million tonnes of rutile and 50 million tonnes of ilmenite, although a substantial proportion of east-coast reserves of rutile are currently unavailable for mining because of environmental considerations.

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, an outlet which now accounts for about 60 percent of total rutile consumption. The use of ilmenite is virtually confined to pigment manufacture. However, the commercial application of processes by which ilmenite is up-graded to approach rutile in TiO_2 content (beneficiated ilmenite or synthetic rutile) provides a feed for either pigment or metal via the chloride process; beneficiated ilmenite now complements supplies of natural rutile and in 1976 beneficiated ilmenite supplied about 25 percent of world requirements of high titania feed. World production capacity for beneficiated ilmenite is about 180 000 tonnes/year.

<u>Zirconium</u>: Australian resources of this metal, in the beach sand mineral zircon, are considerable and are almost twice those of rutile. Again, however, about one-third of east-coast reserves are unavailable to mining because of environmental considerations. 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 for moulds, facings and cores, and for refractories and ceramics, faced over supply 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. In view of the continuing adverse market situation, the floor price for zircon exports was reduced to the range $115-$125/tonne, f.o.b. at the beginning of 1977. To allow more flexibility in approving zircon prices for export, normal export controls were reverted to in March 1977.

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.

<u>Cobalt and Cadmium</u>: Both these metals are by-products in our lead-zinc industry and cobalt is also 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.

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, constituted 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 now about 150 000 tonnes/year. In 1976, production from this source accounted for about 21 percent of total domestic output of rutile concentrates. 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 are available. Exports of ilmenite, rutile, and zircon from Eneabba have begun through Geraldton and are expected to increase substantially in the 1980s.

In 1976, mine production of cobalt toalled 3250 tonnes, of which 97 tonnes were contained in zinc concentrates from Broken Hill, NSW, 1024 tonnes in nickel concentrates produced in Western Australia and 2129 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 20 tonnes of cobalt oxide (14 tonnes of cobalt) from zinc concentrates in 1976. Nickel-cobalt sulphide products are produced at the nickel refinery at Kwinana and the Yabulu 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 co-efficient, 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 1976 was 649 tonnes of metal; 440 tonnes came from Risdon, 185 tonnes from Cockle Creek, and 24 tonnes from Port Pirie. Mount Isa produce a cadmium-thallium sponge which is exported, and reported production of 17.3 tonnes of this material in 1975. Domestic sales in 1975 were about 178 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. Elsewhere in the world, magnesium is produced from seawater; however, there is no production of magnesium in Australia. 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. However, rising gold prices in 1971 and 1972 reversed the trend and production rose to 23 5000 kg in 1972, but then declined and was 15 613 kg in 1976. In 1976, 70 percent of domestic gold production came from gold mines in Western Australia, with a very small contribution from gold mines in Victoria and Queensland. The remainder (30% of production) came from the Northern Territory where, because of low copper prices, Peko-Wallsend Ltd concentrated on the gold-rich portions of the orebodies in the area and stopped production of copper. The major disability suffered by the gold mining industry in recent years was that whereas the price of gold had been fixed for more than 30 years, the cost of production had 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 exceeded $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 in which gold might be traded at higher than the official price; in general, this system together with other measures induced a rising free market price for gold, promised some rejuvenation of gold mining in Australia, but this promise was not fulfilled. 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 by the end of August 1976 it had fallen to $83/fine ounce. By 26 November 1976 the price had recovered to $106. Following devaluation of the Australian dollar on that date the price was $128. After moving downwards slightly mainly on account of the re-valuation of the Australian dollar, it recovered slowly and in December 1977 the price was about $140/ fine ounce.

In August 1976 the Government announced that it had accepted the main recommendation of an IAC report on the gold mining industry published in June 1975. The report advocated the phasing out over 5 years of taxation exemptions to the industry. After representations from interested parties the Government announced in mid-August 1976 that the whole question of assistance, including taxation exemption, to the gold mining industry was being referred back to the IAC for further consideration. After further consideration the Government decided to allow gold miners to retain their tax exemptions for the time being.

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 120 tonnes of combined concentrates in 1976; 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. A small amount is commonly recovered annually as a by-product of gold refining at Port Kembla. Platimum is now recovered from nickel co-products produced at the Kwinana nickel refinery. In 1976 production from this source was 292 kg of platinum group metals.

Imports in 1976 were valued at $2.56 million and exports of 623kg were valued at $1.3 million. Canada and South Africa are among the world's leading producers and overseas demand is strong. Both producer and free market prices, stable in 1969, have since declined as a result of current world oversupply. Any future increase in demand for platinum will depend on the U.S. Environmental Protection Authority's decision concerning the use of platinum in catalysts in converters for the control of pollution from automotive exhaust gases. The EPA has postponed its decision concerning the use of such converters until after 1982.

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 statistics of production are not available for publication. Peko Wallsend Ltd produces concentrates containing gold, bismuth, copper, silver and selenium at Tennant Creek. No payment was received in 1976 for selenium in concentrates exported to the Federal Republic of Germany and it is therefore not recorded as Australian production. Domestic consumption is not large. Leading overseas producers are U.S.A, 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: In the past there was a small annual production of concentrates of bismuth as a by-product of tin and tungsten mining in the Northern Territory and Western Australia. In 1967, the Juno gold mine at Tennant Creek recorded the first domestic production since 1962. Production at Tennant Creek since than has expanded considerably with the production of bismuth concentrates from gold ores at the Peko and Warrego mines. The highest production of 1 169 700 kg was recorded in 1974 but production declined subsequently and in 1976 totalled 325 000 kg. The bismuth occurs with copper and gold and much of the bismuth reports in copper-bismuth flue dust, a by-product of copper smelting. Research is continuing into methods of processing bismuth concentrates to bismuth bullion containing about 90 percent bismuth metal. Imports of bismuth metal totalled 13 940 kg in 1976, having ranged between 5000 and 22 000 kilograms in the period 1970-75. Present uses of bismuth are for alloys with precise melting points and for the production of salts used in the pharmaceutical and chemical industries. The use of bismuth as a metallurgical additive to aid the casting of iron and improve the machinability of aluminium and steel has increased in recent years. The continued strength of this market will depend on production in the ferrous and aluminium industries.

<u>Mercury</u>: Australian reserves are negligible. Mercury was produced early in 1967 for the first time since 1945. In 1976 140 kg of mercury metal was produced as a by-product during refining of Rosebery lead-zinc ores at Risdon. Imports of mercury in 1976 were 44 736 kg; China was the major supplier, accounting for 71 percent of total imports, followed by USSR (25 percent) and Spain (3 percent). World production during 1976 was some 8.4 million kg. World consumption of mercury continued to decline in 1976 because of pollution fears. Demand for mercury is expected to increase at an annual rate of less than 1 percent through 1980.

<u>Silver</u>: Most of the silver mined in Australia is mined as a by-product of lead mining, but some is also produced as a by-product of zinc, copper, and gold mining. Mine production in 1976 was 778 658 kg most of which came from the lead-zinc industry. Silver refined in Australia in 1976 was 254 651 kg and almost all the rest of the silver mine production 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, though there are relatively few deposits mined. 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. World production in 1976 was about 21 9000 tonnes.

<u>Indium</u>: This is 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 totalled 744 655 metric carats in 1975-76, but a considerable amount (177 350 carats) 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 economic deposits being discovered. 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 mineral sands along the eastern coast; a production of 90 tonnes was recorded from this source in 1976. The bulk of domestic requirements is met by imports, mainly from the United States.

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

<u>Arsenic</u>: In 1975, Copper Refineries Pty Ltd at Townsville commenced production of copper arsenite at the rate of about 200 tonnes/ year. This is the first recorded productioh of arsenic on a commercial

scale since 1952. Apart from the production at Townsville all domestic requirements of arsenic are imported. A total of 584 tonnes of arsenic trioxide was imported in 1976.

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. Arsenic is used in insecticides, sheep dips, weed killers, wood preservatives, and in glasses and enamels.

Asbestos: Australia has large resources of blue asbestos (crocidolite) in the Hamersley Range, WA. Deposits of crocidolite near Wittenoom were worked, mainly for export, until 1966 when production ceased because of rising costs. There are few known deposits of amosite or of white asbestos (chrysotile). However, the chrysotile deposit at Woodsreef near Barraba, NSW, which contains demonstrated reserves of 38 million tonnes of fibre-bearing rock, was brought into production in January 1972; output in 1976 was 63 332 tonnes of fibre (exports were 39 266 tonnes). Production is expected to rise to 105 000 tonnes/year of fibre by 1978. A small deposit of chrysotile at Baryulgil, NSW, has been exploited for some years and in 1976 produced 430 tonnesoof fibre. The domestic product is dominantly short to medium fibre and although this satisfies local demand and provides exports to Japan, imports of longer fibre chrysotile and of amosite remain significant. Imports in 1976 were 35 757 tonnes of chrysotile, 8827 tonnes of amosite, and 14 863 tonnes of other varieties, mainly chrysotile fines. Canada and South Africa supplied more than 98 percent of Australian asbestos fibre imports.

Because of its fineness, strength, flexibility and suitability for spinning fibre white asbestos is the most valuable variety. Blue asbestos lacks many of the desirable properties of the white, but is stronger and more resistant to chemical action. No detailed statistics on the consumption of asbestos are collected in Australia but more than 60 percent is known to be used in the manufacture of asbestos cement products.

Barite: Australia has adequate resources of barite which could be brought to production to meet its requirements for strategic reasons. However, most are in remote localities, and as economic development of deposits of any mineral of low unit value, such as barite and many other industrial minerals, is restricted by transportation costs, domestic requirements in previous years have been met partly by imports. Since 1970 imports have made up from 11-44 percent of estimated domestic consumption which has declined from 14 000 tonnes/year in 1970 to 11 800 tonnes/year in 1976, mainly as a result of reduced oil drilling activity.

Barite's principal use is as a weighting agent in drilling muds and the Australian oil exploration industry accounted for about 65 percent of domestic consumption in 1976. Barite is also used as a filler and extender in the paint, varnish, rubber, glass, plastics and paper industries and, because of its high specific gravity, in X-ray - shielding plasters and concretes.

Domestic requirements of barium chemicals are almost entirely imported; the total f.o.b. value of imports in 1976 of precipated barium sulphate (246 tonnes), lithopone (99 tonnes), barium chloride (173 tonnes) and precipitated barium carbonate (1463 tonnes), was $332 000.

The scale of barite mining operations in Australia is small. Production in 1976 of 14 133 tonnes was by 3 companies and about 6 syndicates and individual operators; South Australia has consistently been the principal source of supply, but Australia's total production was greatly increased in 1975 as the result of Dresser Products Australia Pty Ltd establishing a new operation in the Pilbara region of Western Australia. The company commissioned a 50 000 tonnes/year capacity grinding plant at Port Hedland in March 1975 to process output of its North Pole deposit, 100 km east of Port Hedland, in anticipation of renewed drilling activity on the Northwest Shelf. Although this has yet to eventuate, the company is hopeful that in the interim, its operation will be sustained by export demand. The company produced about 3500 tonnes of ore in 1976.

Fluorspar: This mineral is essential to the aluminium, steel, chemical, glass and ceramics industries. Consumption is mainly by way of fluorine - bearing chemicals particularly as aluminium fluoride and synthetic cryolite which is consumed by the aluminium industry, and as hydrofluoric acid which is used by the fluorocarbon industry; in its mineral form it is used as a flux in steel production, aluminium smelting and in foundries, in glass manufacture as an opacifier, flux and refining agent, and in enamels, fibreglass and welding electrode coatings. In 1976 estimated domestic consumpton of fluorspar in its mineral form (CaF_2) was 30 000 tonnes of which some 17 000 tonnes was used by BHP, and 13 000 tonnes was used in production of hydrofluoric acid (HF), at Newcastle and Sydney, and in the other industries. In addition the fluorspar equivalent of imported aluminium fluoride and synthetic cryolite used in aluminium smelting, was about 10 000 tonnes.

Although Australia has no reserves of fluorspar and presently imports all requirements, it does have substantial identified sub-economic resources. Domestic production of about 12 000 tonnes of fluorspar since the Second World War has been from various small deposits but production has been intermittent and generally inhibited by availability of high quality material from overseas at competitive prices. Most recent domestic production was by Leighton Mining NL at Pine Mountain, near Walwa in Victoria, but the company stopped production for economic reasons early in 1974 after producing about 4000 tonnes in the previous four years.

Domestic identified resources of fluorine (F) are substantial because the apatite comprising Australia's large phosphate rock reserves also contain 3.5 percent fluorine. Total identified resources of fluorine are assessed at 65.80 million tonnes (equivalent to 134 million tonnes fluorspar) of which 60.73 million tonnes is contained in phosphate rock, 3.87 million tonnes is contained in fluorspar deposits and 1.2 million tonnes is contained in fluorspar present in low concentrations in accummulated mine tailings at Broken Hill.

Bentonite and Fuller's Earth: The demand for bentonite has decreased in recent years, reflecting mainly the decline in petroleum drilling. Important uses continue to be as a bonding agent in iron ore pellets and in moulding sands. Local production of bentonite in 1976 was from Queensland (319 tonnes), New South Wales (11 071 tonnes), and Western Australia (564 tonnes), and imports totalled 23 102 tonnes ; 9 tonnes of fullers earth was produced in 1976, compared with 18 tonnes in 1975. Deposits of bentonite in various States are being tested, and it is possible that Australian production may rise substantially in the future, although domestic freight rates present restraints to exploitation 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 about 20 000 tonnes of the material each year. Production has been almost continuous since 1896 and amounted to 1480 tonnes in 1976, the shortfall being met from imports. Diatomite is used extensively 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, a d synthetic plastics. The Australian product is not entirely suitable for filtering processes and diatomite for this use is mainly imported; imports in 1976, mainly from USA, totalled 9059 tonnes. Resources for other purposes are adequate. However Mallina Mining and Exploration NL reported in their 1976 Annual Report that the company had decided to start construction of a commercial treatment plant in 1976-77 and that it had a firm order for up to 7000 tonnes/year of diatomaceous earth for use as a filtering medium. Mallina holds diatomaceous earth prospects at Dongara, Gingin and Wanneroo in Western Australia; The Broken Hill Proprietary Company Ltd allowed an option agreement with Mallina to lapse, in November 1975, after constructing a 1500 tonne/year pilot plant at the Dongera deposit.

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 Mukinbudin and Rothsay, Wa, and Broken Hill, NSW, for the potash varieties and the Olary District, SA, for the potash-soda varieties. Production in 1976 was 4519 tonnes. This could be expanded almost at will, but consumption has declined owing to the greater suitability of nepheline syenite - which is not produced in Australia - 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 was last recorded in

1963 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 1367 tonnes in 1976 mainly from China, Korea, Sri Lanka and France.

Gypsum: Australia's resources are very large, known reserves being in excess of 760 million tonnes 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 was exported. As a result of a downturn in the building industry, production and exports in 1975 decreased; in 1976 production improved slightly to 941 944 tonnes and exports decreased still further to 189 975 tonnes.

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. Limestone is mined in Australia for use mainly in the manufacture of cement, as well as for metallurgical, chemical, agricultural and other purposes. In 1976 limestone production was 10.58 million tonnes. Dolomite production for use in the steel industry as flux, and in refractories was 589 087 tonnes.

Mica: Although Australia's resources are probably large, production, in the face of cheap overseas supplies, has been minor and in 1976 no mica was produced in Australia. While the Commonwealth Mica Pool operated, during and after World War II, 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, most mines ceased production.

Imports in 1976 amounted to 970 tonnes mainly from India, China and South Africa. In the event of an emergency, Australia's domestic industry could probably be revived to meet her requirements. Alternative sources of supply include Argentina, Brazil and Malagasy Republic.

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. In recent years, red and yellow ochres have been mined in the Ulverstone-Penguin area of northwest Tasmania and red ochre has been produced in the Weld Range area of Western Australia. Production of mineral pigments in 1976 totalled 1025 tonnes (red ochre). Domestic consumption is very small. Some 3000 tonnes were imported in 1975-76.

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 near Glen Innes, the only recorded production of quartz crystal has been from Mukinbudin, WA - namely, 70 tonnes in 1974. Imports of quartzite and natural quartz amounted to 343 tonnes in 1975-76. Recent developments overseas in synthesising quartz crystal have eased pressure on the need to discover indigenous sources. Some 335 904 tonnes of high-grade silica sand were exported in 1975-76 mainly to Japan 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 currently the only production is from Mount Crawford, SA. Mineral sands in the Eneabba-Jurien Bay area of Western Australia are a large potential source of kyanite, although to date there has been non commercial recovery of the kyanite content. Australian production increased 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 588 tonnes in 1975 and 567 tonnes in 1976 and imports were negligible. Imports of kyanite have been greater, and in 1976, imports under an item which included kyanite, sillimanite, andalusite, mullite and dinas earth, totalled 1302 tonnes, mainly from the United States (1050 tonnes) and South Africa (222 tonnes).

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 by evaporation either of sea water or brines of salt lakes and pans. Domestic production increased nearly six fold in the period 1966-1971, from 655 000 tonnes to 3.788 million tonnes, as the result of progressive entry of new producers producing almost exclusively for export, particularly Japanese needs. All new export-oriented producers established their

Despite Australia's position as a net exporter of crude salt, domestic requirements of salt-derived sodium compounds, particularly sodium hydroxide for the processing of bauxite to alumina, are largely met by imports. Australia's capacity to process salt to sodium compounds is constrained by its limited capacity to also consume chlorine, a by-product of the chemical processing of salt. Domestic imports of sodium hydroxide in 1976 were valued at $52.4 million.

Resources of seawater-derived salt are practically limitless; data on brine resources are incomplete, but resources appear to be substantial. In recent years, as a result of exploration drilling for oil and gas, extensive subterranean beds of salt have been identified, particularly in central and northern Australia, further adding to total resources. However there seems little likelihood of underground deposits being commercially developed in the foreseeable future particularly as investigations to date have not indicated the presence of potash, an associated mineral of some evaporitic salt deposits in other parts of the world, and in which Australia is almost totally deficient.

Sulphur-bearing materials: Commercial deposits of elemental sulphur and sulphur-bearing ("sour") natural gas are not known in Australia and in recent years 50-70 percent of domestic demand for sulphur has been met by imports of brimstone from Canada and the United States, supplemented by occasional shipments from Mexico and Iran. Several oil companies recover sulphur from the processing of imported crude oil; 6588 tonnes of sulphur was recovered from oil refining operations in 1976. Although combined capacity of the 6 recovery plants is about 52 000 tonnes/year of elemental sulphur, actual production depends on the sulphur content of the refinery feedstock and this has been declining since low-sulphur Bass Strait oil replaced high-sulphur imported crude.

operations in Western Australia, along the northwest coast - at Shark Bay (Shark Bay Salt), Lake McLeod (Texada Mines Pty Limited), Dampier (Dampier Salt Limited) and Port Hedland (Leslie Salt Co) - except for Lefroy Salt Ltd at Lake Lefroy, 80 km south of Kalgoorlie. The rapid increase in productive capacity, together with slackening export demand in recent years, has led to a situation of over-supply and a situation where each of the producing companies has suffered financial losses from the start of its operations, despite greatly increased salt prices in recent years, from about A$2.90/tonne f.o.b. in 1972 to about A$7.80/tonne f.o.b. since the November/December 1976 devaluation/revaluation. Government approval for salt exports is presently subject to a satisfactory price which the Government regards to be US$8.13/tonne, equivalent to A$7.20 at the prevailing (December 1977) exchange rate.

Domestic salt requirements are met mainly by production from the eastern States: by ICI Australia Limited at Dry Creek, S.A., and Bajool Qld, by Waratah Gypsum Pty Ltd at Lake MacDonnell, SA, by BHP at Whyalla, SA, and by two Cheetham Salt Limited subsidiaries at Price and Lake Bumbunga also in South Australia, by Cheetham Salt Limited itself on Port Phillip Bay, Corio Bay, Lake Tyrrell and the Linga Lakes in Victoria, and by Central Queensland Salt Industries Limited also at Bajool, Qld.

Total domestic salt production in 1976 was 5.489 million tonnes of which 4.276 million tonnes was exported, virtually all of it from Western Australia. South Australia produced 622 780 tonnes, Queensland 118 009 tonnes and Victoria 128 000 tonnes, for the domestic market. Of total estimated domestic consumption of salt in 1976 of 807 000 tonnes, an estimated 607 000 tonnes was processed to sodium hydroxide and sodium carbonate, and about 200 000 tonnes was used in other industrial and chemical applications and in food processing, table salt and other preparations.

Nevertheless Australia has large reserves and resources of sulphurous materials such as pyrites, metal sulphides (ores of zinc, lead, copper and nickel) and gypsum, and in 1976, 45 percent of total domestic sulphuric acid production of 1.631 million tonnes was derived from indigenous material as a by-product of smelting operations at Cockle Creek, NSW, (lead and zinc), Port Pirie, SA, (lead) and Risdon, Tas, (zinc). Sulphuric acid is also produced at Burnie, Tas, from pyrite, a by-product of copper mining at Mt Lyell and of lead-zinc mining at Rosebery. Small amounts of by-product pyrite are also produced at Mt Morgan, Qld, from copper-gold mining operations there and this material (454 tonnes in 1976) is sold to the domestic glass and steel industries. Recovery of sulphur by Western Mining Corporation Ltd from its nickel refining operations at Kwinana, WA, is an estimated 31 000 tonnes/year, contained in some 130 000 tonnes of by-product ammonium sulphate.

The recovery of sulphur as sulphuric acid from sinter gases of indigenous minerals dates back mainly to the early 1950's when brimstone was in short supply and the Federal Government introduced incentives by way of bounty payments, to promote self-sufficiency. Later, when changing circumstances abroad increased the supply situation, the Government announced that bounty payments would not be renewed after June 1965 but, on re-consideration, the Sulphuric Acid Bounty Act was first extended to 1969, and then to 1972, when it lapsed. Sulphur is consumed mainly as sulphuric acid, Australian demand for which directly reflects demand for phosphatic fertiliser, particularly superphosphate. Although total domestic acid consumption in 1976 was only 1.702 million tonnes, of which 66 percent was used in phosphatic fertiliser production, consumption in recent years has been around 2.0 million tonnes/year of which some 80-85 percent was used in fertilisers. A downturn in fertiliser, and acid, consumption in 1975, reflecting greatly increased phosphate rock prices and Government's decision to terminate the $11.81/tonne superphosphate bounty on 31 December 1974, was reversed in 1976 because Government restored the subsidy from 11 February 1976. However, recovery to historical levels of consumption of fertiliser and acid is likely to be slow because presently depressed farm incomes are themselves unlikely to recover quickly.

The downturn in consumption of fertilisers is especially evident in imports of brimstone; domestic acid production is much less responsive to demand, being only a by-product of smelting operations. Brimstone imports in 1976 totalled 206 000 tonnes, valued f.o.b. at $7.408 million.

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. Western Australia is the only state in which vermiculite is produced. Crude vermiculite was produced sporadically in Australia up to 1965, when production ceased until 1970. Production in 1976 was 716 tonnes. A small amount is imported annually (861 tonnes in 1976), South Africa being the main supplier. 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. Deposits are known in most of the States and, in recent years, Three Springs and Mount Seabrook in Western Australia, and Mount Fitton and Gumeracha in South Australia have been the chief producers. Production of talc in 1976 amounted to 77 447 tonnes of which 62 306 tonnes was exported. Imports, mainly of varieties not available domestically, were 371 tonnes. Production of pyrophyllite from New South Wales totalled 14 494 tonnes the bulk of which was from Pambula on the south coast. 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.

Mineral Fertilisers: Gypsum and limestone are not strictly fertilisers but are, however, used for agricultural purposes in many places. They have been dealt with elsewhere in this paper and it need only be said that supplies are abundant. Phosphate rock is the main component of manufactured fertilisers.

Phosphate Rock: Phosphate rock is used almost entirely for the manufacture of superphosphate, production of which, in terms of single superphosphate equivalent, declined to 1.59 million tonnes in 1975, from 5.35 million tonnes in the previous year but recovered to 2.83 million tonnes in 1976. The downturn reflected consumer reaction to greatly increased phosphate rock prices and to Government's decision to terminate its $11.81/tonne superphosphate bounty; the severity of the downturn was amplified by an element of forward buying in 1974, at subsidised prices. Recovery of consumption was helped by Government restoring the superphosphate bounty from 11 February 1976 but is likely to be slow because farm incomes are presently depressed.

Production of phosphate rock from northwest Queensland's large deposits, first discovered by BH South in 1966, commenced in April 1975. However the project has been beset by flagging export markets and reluctance of Australian fertiliser manufacturers to accept the rock because it is somewhat different to the material to which they are accustomed and thus would require them to modify some of their plant.

Consequently BH South recently announced that it would cut back its production rate to 350 000 tonnes/year of rock despite the fact that it recently completed the first stage of development, viz increasing production capacity to 1 million tonnes/year.

A small quantity of phosphate rock is also produced in South Australia but the material is not suitable for superphosphate manufacture because of its high aluminium and iron content, and, after crushing, is applied directly to the soil by local users; production in 1976 was 5402 tonnes.

Australia's supplies of phosphate rock are drawn chiefly from Nauru and Ocean Island in the Pacific Ocean and Christmas Island in the Indian Ocean. The Christmas Island deposits are 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 managed by the British Phosphate Commissioners (BPC), on behalf of the Australian, New Zealand and British Governments, to 30 June 1967 when the operation was purchased by the Nauruans. 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 its operations. Production from Ocean Island is still controlled by the BPC but these deposits will be depleted by the turn of the present decade; reserves of Nauru and Christmas Island are sufficient for some 25-30 years production. Indeed it was the Australian Government's concern for security of future supply of phosphate rock that prompted it to actively encourage exploration for new deposits, both through its own agency the Bureau of Mineral Resources, and private industry, and which ultimately led to the discovery of the northwest Queensland deposits in 1966. Total mainland identified reserves presently total 2770 million tonnes of rock of average grade 7.39 percent P.

(16.93 percent P_2O_5) and identified sub-economic resources total an additional 2529 million tonnes rock of average grade 5.59 percent P (12.81 percent P_2O_5).

Imports of rock in 1976 totalled 1.20 million tonnes valued at $41 million f.o.b.

Potash: All domestic requirements of potassium salts are imported. In 1976 Australia imported 116 000 tonnes of potassic fertilisers, mostly potassium chloride, from Canada and the United States; the f.o.b. value of imports was $7.1.million.

Commercial deposits of potash have so far not been discovered in Australia although discoveries of such deposits may yet occur. Exploration to date has not been intensive and has been confined to testing of likely drill core material made available by oil drilling operations, and investigations of evaporite deposits associated with the dry lakes of Australia's arid central areas.

At the end of the Second World War, the Western Australian Government sponsored attempts to produce commercial grade potash from an estimated 12 million tonnes of alunitic red mud in Lake Campion, W.A. The deposit was worked to 1949, when operations ceased for economic reasons, after about 175 000 tonnes of alunite (a potassium-aluminium silicate mineral) had been treated for production of some 13 000 tonnes of potassic fertiliser.

In November 1973 Texada Mines Pty Limited commissioned plant to produce langbeinite ($K_2 Mg_2 (SO_4)_3$) from the residual brine liquor of its salt (sodium chloride) producing operations at Lake McLeod, WA. The project was beset by technical problems, declining export markets and ultimately by flooding.

The langbeinite operation has since been put on care and maintenance pending further feasibility studies. About 10 000 tonnes of material, produced and stockpiled during progressive commissioning of the plant, was sold overseas in 1976 after BHP bought a controlling interest in the company.

Nitrates: Commercial deposits of nitrates are not known to exist in Australia and most requirements for nitrogenous fertilisers and nitrates for industry are manufactured domestically, with minor imports supplementing requirements. The starting point of all production is ammonia, the nitrogen content of which is either produced or recovered from various sources including natural gas, refinery gas, coke-oven gas air and imported naphtha.

Consumption of nitrogenous fertilisers has increased markedly since 1966 when the Commonwealth Government introduced the Nitrogenous Fertiliser Subsidy Act which provides a benefit of $78.74/tonne contained N to consumers of nitrogenous fertiliser; the steady increase of consumption is partly 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 contained elemental nitrogen (N) in 1975-76 was 165 700 tonnes. Production statistics for some products are not available for publication, but output in 1975-76 totalled about 13 000 tonnes of product containing an estimate 3400 tonnes N.

In its report Nitrogenous Fertilisers Subsidy, 5 September 1975, the IAC recommended that the $78.74/tonne subsidy be terminated over a period of 3 years. After deferring its decision in 1976, the Government reduced the subsidy to $60/tonne contained N from 1 January 1977.

Petroleum*: Australia's main mineral deficiency has long been that of indigenous petroleum particularly crude oil, the lack of which has compelled her to import significant amounts of crude oils and refined products to meet her increasing consumption. In 1976 the value of imports of refinery feedstock and refined products rose to $865.7 million (crude $563.2 million) from $733.7 million (crude $489.7 million) in 1975 mainly as a result of increased imports; imports accounted for about 36% of Australian petroleum requirements; indigenous crude oil supplied about 69.9% of demand in 1976. The rate of increase in consumption of marketable petroleum products was 3.9% over the previous year, but demand is expected to almost double in the next 10 years . The average annual increase in consumption of the same range of products for the five years ended 31 December 1976 was 4.8 percent.

With 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 1.2 million cubic metres (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 2.16 million cubic metres (13.8 million barrels), in 1969, 2.51 million cubic metres (15.8 million barrels), or 8.8% of total petroleum consumption, and 10.35 million cubic metres (65.1 million barrels) in 1970. Production rose rapidly to 17.95 million cubic metres (112.9 million barrels) in 1971 as the Gippsland Shelf fields came on stream. In 1976 indigeneous crude oil production was 24.2 million cubic metres (152.2 million barrels).

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 85; in 1968 the total was 83; in 1969 the number of exploratory wells completed was 99, rose to 119 in 1970 and fell to 72 in

* Prepared by Petroleum Exploration Branch

1971, rose to 100 in 1972 and fell to 60 in 1973, to 51 in 1974, to 25 in 1975 and to only 20 in 1976 and 21 in 1977. However, based on exploratory programs announced for 1978 the number of exploratory wells could rise, to between 33 and 46 this year.

Part of the reason for the increasing tempo of oil search in Australia in the 1960s undoubtedly derived from the Commonwealth's policy of subsidising private companies' expenditure under a scheme first introduced in 1958, extended to June 1969, and further extended until its termination in 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 and Sydney with natural gas; 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 the Boxleigh - Silver Springs fields in Queensland for which development plans are well advanced, Mereenie - Palm Valley in the Northern Territory and fields on the North West Shelf off Western Australia. Gas has also been discovered in the Tern well, 300 km west south west of Darwin, and several major discoveries of natural gas on the Northwest Shelf are being appraised and production plans formulated. Gas from the Tuna field in Gippsland Basin is expected to be brought into production after 1979.

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 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 Mackerel and Tuna oil fields are to be brought into production in 1978 and 1979 respectively. At the end of 1976 the production platform at Mackerel had been installed and development drilling was in progress at the end of 1977. The Tuna platform has been installed and is being prepared for development drilling expected to start in the second half of 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. 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 drill 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 coast 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 1976 crude oil production was some 61 225 cubic metres per day. Natural gas production from this area also began in 1969 and some 3038 million cubic metres were produced in 1976.

Further offshore dilling units arrived in Australia, and by mid-1969 six mobile units were operating in Australian coastal waters. Three of these units were drill 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 1975, only 2 units Ocean Digger and Ocean Endeavour, both Australian flag units, were in operation at the end of 1976. At the end of 1977 four mobile offshore units were active and one platform rig was active on the Mackerel platform. At the end of 1976, some 285 wells were on production in the Barrow Island field, and total daily crude oil production was around 5025 cubic metres per day (35 222 barrels 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 1977 was delivering about 14.5 million cubic metres per day (410.0 million cu. ft/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 1977 was being sustained at a daily rate of some 0.70 million cubic metres per day (24.7 million cu. ft./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 5.44 million cubic metres per day (192.2 million cu. ft/day) in the September quarter of 1976 prior to gas being supplied to Sydney. The natural gas line to Sydney from the Cooper Basin fields in South Australia was brought into service in late 1976 with natural gas being supplied to Sydney consumers in late December. Average rate of gas production from the Cooper Basin fields in 1977 was 7.0 million cubic metres/day (250 million cu. ft/day. Natural gas was delivered to the Perth area from the Dongara field in October 1971 which is currently delivering gas at a rate of 2.26 million cubic metres per day (80.0 million cu. ft/day).

In 1977 indigenous crude oil production from proven fields supplied about 69.9% 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 import 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 3.2% 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 and oil shale. 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 realised. 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

It is perhaps not generally known how much effort goes into the topographic, geological and geophysical mapping program, or how far it has already advanced.

The Division of National Mapping in the Department of National Development provides a focus for the various Government agencies engaged in this widespread and important activity. Overall coordination of the topographic mapping program, both Commonwealth and State, is provided by the National Mapping Council, consisting of the Director of National Mapping (Chairman), the Director of Military Survey, the Commonwealth Surveyor General, the Hydrographer RAN, the Director of the Central Mapping Authority in NSW and the Surveyor General in each of the other States.

The Commonwealth undertakes all topographic mapping within its own territories and is active in most States. Commonwealth agencies are the Division of National Mapping (Department of National Development), which has the primary responsibility, and the Royal Australian Survey Corps (Army), which does a substantial amount of work. The basic scale of topographical mapping is 1:100 with 20-metre contours. For about one-half of Australia, the populated areas and the coastal fringe, line maps are to be published at this scale, of which about half are now available. For the central portion, orthophotomaps with 20 m contours will be published at 1:100 000, backed up with line maps at 1:250 000 with 50 m contours, which will eventually cover the whole of Australia, and replace the existing, mainly uncontoured, non-metric 1:250 000 series. There is complete interchange of data between members of the National Mapping Council, both Commonwealth and State, to minimise cost.

National Mapping also is undertaking a program of bathymetric mapping of the continental shelf at 1:250 000 (contour interval 20 m) and to date about 30 of the 250 sheets have been printed. Mapping at larger scales if produced by the States, and by the Army for training purposes, and National Mapping maintains a 1:10 000 series of all populated places of more than 250 people, primarily for census collection purposes. The area covered by this larger scale mapping is of course limited. Air photographs of the whole of Australia are also available.

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 is several times as long at least. However, over 90 percent of the continent has been covered since World War II, and mapping is expected to be completed by 1980.

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. BMR completed a reconnaissance marine geophysical survey of the Australian continental margin several years ago. 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 both offshore and onshore. 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.

The general situation regarding Commonwealth income tax in the mining industry is as follows.

- The income tax rate is 46% of taxable income
- Petroleum miners' exploration and development expenditure is deductible against income from any source (previously it was deductible only against petroleum income).
- For other mineral exploration there is an immediate deduction of mineral exploration expenditure incurred anywhere in Australia, against income from mining activities only.
- All capital expenditure at the mine site (except exploration expenditure, which is written off immediately as above) of both general mining and petroleum mining can now be written off on a reducing balance basis at the rate of 20% (that is the miner can write off each year 20% of the accumulated capital expenditure remaining after last year's tax, so that after 5 years he will have written off 67% of the total). Previously the rate was 4% per year, so this is a considerable concession. In the case of a mine with an estimated life of 5 years or less he can write off the capital expenditure by annual instalments over the life of the mine.

- For capital expenditure away from the mine site (for transport facilities, for example, or for most port facilities) the capital expenditure can be deducted over 10 years or 20 years at the option of the tax payer.

- The "investment allowance" (which applies to all industries) is 40% of the value of almost all depreciable equipment ordered before 1 July 1978, and then 20% if ordered before 1 July 1983.

Particular minerals have in the past been given specifically favourable taxation treatment in the form of a 20% exemption from tax because it was feld that a national need existed to foster their exploration; and gold mining as a special case has been free of income tax since 1924. The 20% exemption from tax for particular minerals has now been removed, but profits from gold mining are still tax free.

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 occasionally 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.

Concluding remarks: 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

	1972/73		1973/74		1974/75		1975/76		1976/77 (a)	
	Value (f.o.b $'000)	%	Value (f.o.b. $'000)	%	Value (f.o.b. $'000)	%	Value (f.o.b. $'000)	%	Value (f.o.b. $'000)	%
Industrial Groups -										
Agriculture	831 315	14.0	1 112 895	16.7	2 257 736	27.0	2 105 953	22.7	2 138 542	18.8
Pastoral -										
Wool	1 130 467	19.0	1 156 564	17.3	753 492	9.0	961 979	10.4	1 477 000	13.0
Other	1 128 266	19.0	1 023 457	15.3	626 700	7.5	913 276	9.9	1 304 411	11.5
Dairy and farmyard	164 445	2.8	165 042	2.5	173 896	2.1	212 971	2.3	204 460	1.8
Mines and quarries (other than gold) (b)	1 252 386	21.1	1 563 608	23.4	2 253 596	26.9	2 651 741	28.6	3 419 394	30.1
Fisheries	75 508	1.3	68 941	1.0	71 331	0.9	83 474	0.9	143 762	1.3
Forestry	9 139	0.2	11 058	0.2	12 085	0.1	11 674	0.1	12 431	0.1
Total Primary Produce	4 590 526	77.3	5 101 568	76.5	6 148 836	73.5	6 941 068	74.9	8 700 000	76.5
Manufactures	1 204 980	20.3	1 380 504	20.7	1 933 341	23.1	1 991 517	21.5	2 363 915	20.8
Refined petroleum oils	43 144	0.7	100 817	1.5	157 443	1.9	159 636	1.7	200 299	1.8
Unclassified	98 515	1.7	89 963	1.3	128 135	1.5	173 546	1.9	112 531	1.0
Total Australian Produce	5 937 165	100.0	6 672 852	100.0	8 367 756	100.0	9 265 766	100.0	11 376 745	100.0

(a) Preliminary (b) value of gold included for 1976-77

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 accompany 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; assessments of reserves of copper and tungsten are 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 mobilisation. 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 fo 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

1976

Availability of Supply				Mineral Processing			
Metal or Mineral	Distribution	Domestic Identified Resources	Current Raw material Imports	Level of Processing	Distribution	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, and Qld. Minor-NSW, 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

Availability of Supply				Mineral Processing			
Metal or Mineral	Distribution	Domestic Identified Resources	Current Raw material 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

Availability of Supply				Mineral Processing			
Metal or Mineral	Distribution	Domestic Identified Resources	Current Raw material 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

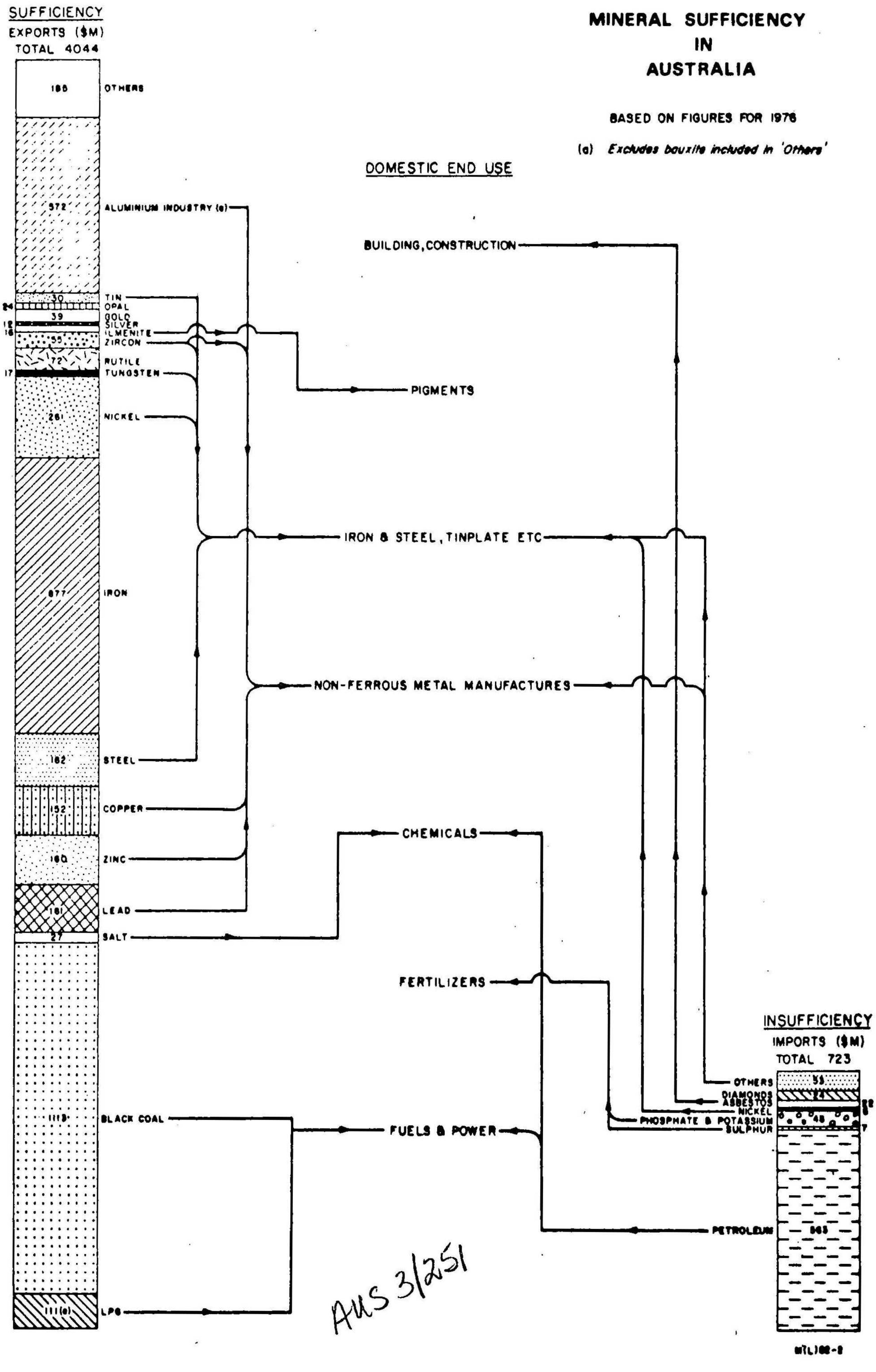
	Availability of Supply			Mineral Processing			
Metal or Mineral	Distribution	Domestic Identified Resources	Current Raw material Imports	Level of Processing	Distribution	Current Imports	Possible Disadvantages in Emergency
Chemical Fertilizers							
Phosphorus (Phosphate rock)	NW Qld	Very large	All requirements	-	Fertilizer made in all states	Some mixed fertilizers	Domestic resources only in NW Qld.
Potassium	WA	Appear adequate	All requirements	-	Fertilizers all states	Some mixed fertilizers	Deposits remote from factories.
Sulphur	(sulphides) well distributed	Elemental nil, sulphide large	50-70% of requirements	Acid plants	Well distributed	-	
Salt	Well distributed	Unlimited	-	Salt, sodium hydroxide chlorine	Well distributed	Some chlorine, 50% caustic soda requirements	

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

	Availability of Supply			Mineral Processing			
Metal or Mineral	Distribution	Domestic Identified Resources	Current Raw material 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	About 60% magnesite imported	No metal produced	-	All metal	Metal can be produced as in World War II.
Nuclear							
Uranium	Northern Australia, WA & SA	Large	-	U_3O_8 (yellow cake) radio-isotopes	Northern Australia Sydney	Radio-isotopes	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, heavy crudes	Major supplies offshore. Import of heavy crudes

<u>SUMMARY OF AUSTRALIAN MINERAL INDUSTRY</u>

	Availability of Supply			Mineral Processing			
Metal or Mineral	Distribution	Domestic Identified Resources	Current Raw material Imports	Level of Processing	Distribution	Current Imports	Possible Disadvantages in Emergency
<u>Minor Metals</u>							
Vanadium	WA Qld (oil shale)	Probably large not developed	-	-	-	All vanadium & composites	No production
Bismuth	Mainly NT	Adequate - NT	-	Bismuth concentrates containing gold & copper	-	All metal	Small metal capacity
Cobalt	Eastern Australia, WA	Adequate (from nickel ores)	-	Oxide (by product)	Tasmania WA & Qld	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
BASED ON FIGURES FOR 1976
(a) Excludes bauxite included in 'Others'
SUFFICIENCY
EXPORTS ($M)
TOTAL 4044
OTHERS
372
ALUMINIUM INDUSTRY (a)
30
TIN
24
OPAL
39
GOLD
12
SILVER
16
ILMENITE
55
ZIRCON
72
RUTILE
17
TUNGSTEN
261
NICKEL
877
IRON
182
STEEL
152
COPPER
160
ZINC
161
LEAD
27
SALT
1113
BLACK COAL
111(a)
LPG
DOMESTIC END USE
BUILDING, CONSTRUCTION
PIGMENTS
IRON & STEEL, TINPLATE ETC
NON-FERROUS METAL MANUFACTURES
CHEMICALS
FERTILIZERS
FUELS & POWER
INSUFFICIENCY
IMPORTS ($M)
TOTAL 723
OTHERS
DIAMONDS
24
ASBESTOS
NICKEL
PHOSPHATE & POTASSIUM
45
SULPHUR
7
PETROLEUM
AUS 3/251