DEPARTMENT OF
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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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MINERAL RESOURCES OF AUSTRALIA
-1973-

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INTRODUCTION

This paper, designed for Industrial Mobilisation Courses in 1973, attempts to give a broad picture of Australia's mineral industry, and of the varied and widespread resources on which it is founded. It includes a quick glance at the history of the industry and the domestic requirement for the principal minerals and ores, some notes on the chief deposits and centres of production, reference to some of the industrial activities dependent on minerals, remarks about recent important events in mineral exploration, and an attempt to foresee what lies ahead. Two important minerals, coal and underground water, are being dealt with by other speakers to the Course and, though both are of vital importance to the national economy, they will not be included in the present discussion.

Even with these exceptions, the topic is still very large. Australia's known mineral wealth has increased with every decade since the first major discoveries more than a century ago, and the end still seems far from sight. Our growth as a nation has owed much in the past to the flow of population and capital which followed the early mineral discoveries. This flow reached a peak towards the end of the last century, then slackened for almost fifty years; it has begun again in the last decade in the wake of exciting discoveries from which great new sources of wealth are foreshadowed. Today there is promise of development on a scale not to have been imagined even a decade ago.

The new era in mining development in Australia with its rash of discoveries and subsequent exploitation stemmed from many related factors - new exploration tools and concepts, the inducement to Australia of foreign capital and expertise, the rise of Japanese markets and the advent of bulk carriers to name a few - and has resulted in recent years in the mining industry replacing wool as a main stay of the economy at a time when rural industries in general are depressed. Statistics available do not indicate the real contribution of the mineral industry to G.N.P. but the value of exports of industrial groups within Australia, given in Table 1, show the rising impact of the mineral industry on overseas funds as the largest single export earner in recent years. The contribution of mines and quarries in 1971/72 given as 23.3% 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"; if the value of alumina is added to mineral exports the contribution rises to 26.2%.

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; need for foreign capital for both exploration and development continues to erode Australian equity in the industry; restricted domestic markets for processed products, amongst other factors, continue to place restraints on mineral processing; and the prosperity of the industry, inevitably based on exports although benefiting from long term contracts, remains heavily dependent on the Japanese economy, which currently provides markets for 56% by value of our mineral exports. Indeed the slowing down of the Australian mineral industry in 1971/72, as a result of lower world metal prices and of checks to the economy of both U.S.A. and Japan in particular, serves as a salutory reminder of our vital concern with world economies and of our need to diversify our mineral trade as much as possible.

Reactions from Australian and foreign stock exchanges, the inevitable failure of some ill-equipped small mining companies and other regrettable but spectacular events following recent boom years tended to exaggerate the situation and to obscure the facts that in terms of development and production the industry has continued to progress. The phenomenal rate of annual increase in production has been lowered but not reversed. The value of ex-mine production and of exports rose in 1972 over those of 1971 and on evidence to date these will continue to rise in 1973, and 1974; moreover, exploration funds continue at a satisfactorily high level and significant increases in production and exports in the latter half of this decade seem assured.

One feature of the new epoch, perhaps worthy of comment, is the degree to which Governments have become involved with industry both in exploration and development of major mineral deposits. 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 block diagram showing values of imports and exports of minerals in 1971, which is attached at the end of the report. The table and block diagram are perhaps more effective in illustrating the present satisfactory situation than any amount of text can hope to be.

The minerals discussed are grouped under the following headings -

(a) Iron, manganese, chromium and other metals commonly used in the manufacture of steel;
(b) Base metals - copper, lead, zinc, and tin;
(c) Uranium, thorium, and other metals used in or in connection with the production of nuclear energy;
(d) Beach sand minerals - rutile, ilmenite, zircon;
(e) Other metals;
(f) Non-metallic minerals;
(g) Fertilizer minerals;
(h) Petroleum (i.e. oil and natural gas).

Mineral statistics given are those for 1971, the latest calendar year for which complete figures are available.

DEVELOPMENT OF THE MINERAL INDUSTRY

The Australian mineral industry is in reality as old as the nation itself, as it commenced with the first quarrying and shaping of Hawkesbury Sandstone for early buildings at Sydney Cove. 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. First discovery was made in the Newcastle area by escaped convicts in 1791; discovery of coal in the south coast followed a few years after and the coal mining industry commenced near Newcastle in 1799.

Although traces of some metallic minerals, particularly gold, were recorded from time to time in the early decades of the 19th century, metalliferous mining did not commence until the 1840's when mining of silver-lead ores commenced in 1841 near Adelaide in territory subsequently to become South Australia. This was followed by the initiation of copper mining 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 1860's.

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

It was not long before new interest and expertise in prospecting led to the discovery and exploitation of other metals; the commencement of tin mining near Inverell, New South Wales in 1871 and at Renison Bell Tasmania in 1872 heralded very significant tin production in eastern Australia, which in fact became the major world source of tin for nearly a decade in the late 70's and early 80's. Copper mining was rejuvenated by discoveries at Cobar, N.S.W., in the early 70's, and the finding of Mount Morgan in Queensland in 1882 and of Mount Lyell in Tasmania in 1885, although both deposits were first mined for gold, provided major 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 west 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 mining industry continued to prosper in the early years of the twentieth century but after the first decade fortune began to change and a general decline in both production and ore reserves of copper, gold, and tin continued at least until the 1950's, although gold production temporarily revived in the 30's. Only silver, lead, and zinc production and exports, based on Broken Hill in New South Wales, showed general increases in this period; they continued as a solid base for the mineral industry for most of the first half of this century, in which problems of falling domestic production and lack of new major discoveries became more obvious and challenging as 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 lead (pig) substantially increased in the second decade and was joined by refined tin and by significant increases in refined zinc after 1917. 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 becoming the centre for expanded steel production. Detailed planning eventually led to the establishment by Broken Hill Pty Coy Ltd of steel works on the coast at Newcastle, New South Wales, in 1915 and although faced with problems in both the 1920's and the 1930's, steel making was firmly established and expanded. Another enterprise, G. & C. Hoskins, eventually transferred steel making from Lithgow to the coast near Wollongong in 1928 but subsequent trouble in the depression in the early 1930's led to this project being taken over by Broken Hill Pty Coy Ltd in 1932.

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

The need for new ore reserves of many minerals was probably the major concern of the industry in the late 1930's and early 1940's 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 tons, was a reaction of the Commonwealth Government to this concern.

It is therefore all the more remarkable than that within the next decade, in fact in 1949, began a series of ore discoveries which continues 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 with either incentives for exploration and development, including higher metal prices, or with the tools by which they can be accomplished. The combination of mineral potential in Australia, particularly in the extensive areas of Precambrian rocks which have provided the bulk of the world's metals, political stability and Governmental assistance for exploration and mining attracted both domestic and foreign companies to Australian fields. The general policy of Government of providing basic scientific information, and an encouraging climate for mineral exploration, but leaving private enterprise comparatively free to search, discover and develop, paid off handsomely.

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

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

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 $1,300 million in 1971 to provide currently nearly 30% of Australia's overseas earnings and to replace wool since 1968 as Australia's largest export earning group. The mineral industry produced in 1965 what was probably the first favourable balance of overseas mineral trade this century; this favourable balance has grown from $5 million in 1965 to $1,100 million in 1971 and will undoubtedly continue to increase in the decade ahead.

Moreover, the rise of the mineral industry was timely, happening at a time when wool and most other rural industries were in difficulties, and doubtless saving Australia from currency devaluation and import restrictions in the late sixties. Reserves of iron ore, black coal, and bauxite, which support over 60% of Australian mineral exports, are very large and, combined with long term contracts and rising demand for minerals throughout the world, promise continued major production and export.

However, upsurge of the mineral industry since the second world war brought problems as well as achievements. The cost of exploration and development far exceeded the funds available in a country with a population of 12 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 60% self-sufficiency in 1972 is to last.

Restricted domestic markets for processed products, internal costs and other factors continue to place restraints on domestic mineral processing and thus on the added value achieved by processing. Again the prosperity of the industry, inevitably based on exports, remains heavily dependent on the Japanese economy, which provided markets for 56% of Australian mineral exports in 1971. Indeed the slowing down of the Australian mineral industry in the latter half of 1971, as a result of lower world metal prices and of checks to the economies of U.S.A. and Japan in particular, was a salutory reminder of Australia's dependence on world economies and of the need to diversify mineral trade as much as possible.

Iron and Steel: Production of iron ore for iron and steel making in 1971 was about 61 million tons, an increase of 21 percent above the output in 1970, due largely to expanding export contracts, although the percentage increase was two thirds of that recorded in 1970. Production of ingot steel in Australia in 1971 fell by 1.21% from 6.71 million tons in 1970 to 6.63 million tons in 1971 and production of pig iron decreased by 0.3% to 6.03 million tons in 1971. Decrease in steel production in 1971 mainly resulted from sluggish markets at home and abroad. Most of the steel was consumed on the domestic market; some 120,000 tons worth $9 million were exported in 1971.

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 60% of our ferroalloys are imported.

The main supplies of iron ore for the Australian blast furnaces came from two sources, the Middleback Range in S.A. and Yampi Sound near Derby, W.A. These two localities produced 6.8 million and 3.6 million tons of iron ore respectively, of which a total of 9.4 million tons were used for domestic steel making. An additional 1.9 tons was mined at Koolyanobbing near Southern Cross, W.A., 106,000 tons of which was used to feed a small charcoal-iron plant at Wundowie near Perth which produces special grades of pig. Imports of iron ore with high manganese content from New Caledonia for blending with domestic ore have been falling in recent years but 2000 tons of magnetite were imported from the Philippines in 1971. In addition to the iron ore consumed in Australia, about 46 m tons of ore and 6 m tons of pellets were exported; this compares with 35 million tons of ore and 5 million tons of pellets in 1970. The Northern Territory and Tasmania continued an export trade, and the overall effect as a 28% increase in export tonnage during the year.

In the not too distant past, the chief cause of concern in matters of iron and steel was the rather low figure of domestic reserves. However, since 1961 the figures for known resources of iron ore have undergone a transformation and we have emerged suddenly as one of the world's major potential producers. This is all the more interesting because until late in the 1950's most authoritative opinions still held the reserve figure 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 had already been established.

To illustrate the spectacular change in our reserves it may be noted that in 1959 the official estimate of demonstrated reserves amounted only to 369 million tons. 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 north west 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 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 north-western part of the State. Recent discoveries in Western Australia include deposits of hematite and of limonite; early development at Mt Tom Price, Mt Whaleback, Mt Goldsworthy and at 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 subjected to vigorous testing and extremely large tonnages of high-grade ore have been demonstrated. Though the full extent is not yet known, informed guesses have placed the total reserves at around 20,000 million tons, and some believe much more. In other words since 1959 our known resources have increased some forty-fold at least and all anxiety for adequate domestic supplies has been removed for many years to come.

In fairness one should remark, however, that 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 than is presently realised. As a result of successful research carried out in the B.H.P. laboratories, low-grade jaspilites of the Middleback Range, previously discarded as waste, are now capable of being 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, however, 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 the year.

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

Investment in the iron and steel plant has been running at above a hundred million dollars annually for several years. New major plant items commissioned since 1962 were a ferro-alloy plant at Bell Bay, Tasmania; an electrolytic tinning line, a new open hearth furnace, a high-speed pickle line and a second hot roll processing line 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. A second blast furnace and an integrated steel plant at Whyalla opened in 1965, where 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. A new major expansion program at a cost of $150 million has been announced recently for Port Kembla; and a pelletizing plant in northern Tasmania came on stream in 1968.

The slowing down of economies both at home and abroad in 1971 resulted in cut downs in steel production of some 6-7% but markets began to improve before the end of 1972.

Manganese is one of the key metals in the manufacture of steel, its chief use being as a de-oxidizer and a de-sulphurizer in the plant process; adequate supplies of its ores are an essential for the long range security of the steel industry. Current usage requires about 30 lb of manganese dioxide for every ton 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 1971 114,000 tons of metallurgical grade 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 1950's, 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 north-western Western Australia, during which many new small deposits were revealed, amounting in all to several million tons. In 1960 a discovery of much greater importance was made by the Bureau of Mineral Resources at Groote Eylandt, on the Gulf of Carpentaria, where B.H.P. have now established an open cut mine and treatment plant. An agreement was entered into with the Commonwealth Government for the Company to erect a ferromanganese plant in the Northern Territory when this can be done economically. 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 1100 tons per year.

Australian production of manganese ore in 1971 was about 1 million tons, of which 781,000 tons were exported, mainly to Japan. Imports have shown a marked decline from 1965 and were about 3,600 tons of ore with 122 tons of manganese metal in 1971. Australia's production of high carbon ferromanganese now satisfies local demand, but imports of other grades including powder totalled 12,000 tons in 1971. The principal localities of production of manganese ore were in the western part of Western Australia, between Meekatharra and Port Hedland, and at Groote Eylandt.

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

The principal deposits are in Tasmania and the Northern Territory. Wolfram comes mainly from Avoca, Tasmania, where Aberfoyle and Storey's Creek mines have been the principal producers; and from Hatches Creek, Northern Territory, which has a satisfactory potential in an emergency, and provided 11 tons of concentrate in 1969. A major deposit of scheelite exists on King Island, Bass Strait, but fluctuating world prices have made operations irregular in recent years and for a time the mine depended upon the receipt of a Government subsidy. A fresh contract has revived operations in recent years, and known reserves have increased sharply from 1.47 to 6 million tons, 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, but world prices remained reasonably firm during 1969, improved in 1970, but generally declined in 1971 and 1972.

Australian production in 1971 (expressed as concentrates of 65% WO_3 content) was 2,494 tons, and recent enhanced prospects on King Island promise higher production of scheelite in the future. The total domestic consumption would seldom exceed 100 tons per annum, its main use being in the manufacture of tungsten-carbide tipped tools.

Molybdenum: Before 1920 substantial quantities of molybdenite were produced in Australia but for many years production has been small; there was no recorded production in 1967 but about 10 tons of concentrates were produced in 1968, about 90 tons in 1969, 113 tons in 1970, and 22 tons in 1971. Imports in 1971 amounted to 358 tons of ore and concentrates, and 219 tons of ferro-molybdenum.

Most of the molybdenite deposits in Australia occur in pipes for which development at any depth is costly. One exception occurs at Yetholme, New South Wales, where some 800 tons 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. Recently there have been reports of some success in testing extensions of an old deposit near Mareeba, Queensland, and a small mine near Glen Innes, N.S.W., which was worked in 1966. Possible recovery of molybdenum as a by-product from treatment of scheelite at King Island in the future could supply only a fraction of our demand.

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

Chromium: Chromite, the ore which yields the metal chromium, has two uses in the steel industry;- as an ingredient in the production of alloy steel; and as a chemically inert furnace lining. Its other main use is for the manufacture of chemicals. Australian annual consumption of chromite runs at about 17,500 tons all of which is normally imported. In 1971, 25,000 tons of chromite were imported, mainly from the Philippines, since Rhodesian supplies were not available because of sanctions. Imports of ferro-chrome rose to 25,000 tons in 1971.

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

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

Nickel: Australia's resources in the past have been small and no domestic production was recorded after 1938. All our requirements were imported and the level had been rising in recent years because of the increased demand for special steels and the greater use of nickel anodes for electroplating. Imports of nickel increased from 1,100 tons in 1966 to 2,005 tons in 1970, while imports of nickel products also rose significantly.

Nevertheless the tightening position of world supplies in the 60's led to intensive exploration in Australia, and many important deposits have come to light. At Kambalda, in Western Australia, the Western Mining Corporation has proved reserves estimated at 20.5 million tons of sulphide ore averaging 3.4% nickel, plus 1 million tons of silicate and oxidized ores.

Drilling by Great Boulder Gold Mines and North Kalgurli (1912) Ltd at Scotia near Kalgoorlie has revealed over 1 million tons of high grade (3%) nickel sulphide ore plus 2.0 million tons of 1.41% nickel at neighbouring Carr Boyd Rocks; mining at Scotia commenced in 1970, and is scheduled to start at Carr Boyd Rocks when markets become available. Poseidon at Mount Windarra reports ore reserves of 5-6 million tons averaging 2.18% of nickel, with a cut off grade of 1% nickel, and development of the mine is underway. Ore shoots discovered by Anaconda-C.R.A., Selcast, and B.H.P. - International Nickel promise additional production in the future and extensive exploration continues. Although discovery of such relatively high grade orebodies is most likely to continue in this field, these 'shoots' are comparatively small and isolated and thus present problems in large scale development. Of major importance in 1971 were the discovery and exploration of large but low grade deposits in the Mt Keith area, north of Kalgoorlie, where mining by open cut is feasible, and of extensive higher grade deposits (Agnew) in the same geological environment. Difficulties include provision of water, infrastructure, capital and markets, but feasibility studies are in hand.

Furthermore, recent prospecting for lateritic nickel deposits in Australia has discovered major deposits at Wingelinna in Western Australia but close to the border with South Australia, and smaller deposits at Greenvale and near Rockhampton, Queensland; feasibility studies completed in 1970 by International Nickel indicate that deposits at Wingelinna are not currently viable, but a partnership of Metal Exploration and Free Port Sulphur plans to develop the Greenvale deposit to produce 25,000 short tons of nickel in nickel oxide and 1200 short tons of cobalt yearly from a refinery at Townsville from 1974.

Production of nickel concentrates commenced in June 1967 at Kambalda and the output by the end of the year was 15,800 tons with a nickel content of 2061 tons, all of which was exported mainly to Japan. Production of nickel in concentrates increased to 4573 tons in 1968 - roughly equalling Australia's consumption of nickel - and to 35,000 tons in 1971, mainly from Kambalda but including production from Scotia (Great Boulder - North Kalgoorlie). Current mine and mill developments promise about the same amount of nickel in concentrates from the Western Australian field in 1972; sluggish markets for nickel continue to restrict development of some new mines, but additional production is expected in Western Australia by 1974. In 1971, about 50% of nickel concentrates were domestically processed; the smelter at Kambalda and the refinery under way at Townsville will increase this level, of processing. A nickel refinery installed by Western Mining Corporation at Kwinana, Perth, with a capacity of 17-18,000 tons of metal per year came on-stream in early 1970, and produced at the rate of about 15000 tons per annum in 1971 from nickel concentrates from Kambalda. In addition, construction of a nickel smelter was started near Kambalda in 1971 with production of nickel matte planned for 1973.

BASE METALS

Copper: Australia, which has again become entirely self-sufficient in copper, had an important early history of production which began as early as 1842 in South Australia; during the first half of this century her main deposits were slowly exhausted, no new ones were found, and it looked as though she would become largely dependent upon imports. This possibility was dispelled some years ago in the mid-fifties by the discovery of very large reserves of copper ore adjacent to the lead-zinc lodes at Mount Isa. Since then other deposits have been found in several parts of the continent, and working mines like Mt Lyell have been shown to have greatly increased reserves. Active exploration is being continued in Australia and New Guinea and today we can provide not only for our own needs but for a significant export trade as well. Production from Bougainville began in April 1972 and is likely to reach 160-180,000 tons of metal per year in 1973.

The Australian scene is dominated by Mount Isa, which produced 65% of the total in 1971 and which has reserves sufficient to support a high rate of production for well over 30 years. Other important centres are Mount Morgan, Qld., Mount Lyell, Tas., Tennant Creek, N.T., and the recently rejuvenated C.S.A. mine at Cobar, now in production with an annual output expected to reach about 20,000 tons metal in the mid 70's, which is likely to make it the third largest domestic producer.

It is interesting to observe that the full potential of the Mount Isa deposits was not realized until the early 1950's, although copper was mined for emergency purposes from some minor lodes during the war years. After the discovery by drilling of high-grade copper lodes, a major new enterprise got under way in 1953 and output has grown steadily. It fell, following the 1965 industrial upset, to 55,000 tons of metal but a substantial recovery and expansional took place with the completion of the job of relaying the Mount Isa-Townsville railway line for heavier traffic. As a result, record levels of production were achieved in 1966.

Australia has two copper refineries - at Port Kembla and at Townsville. A third at Mt Lyell was closed down a year or two ago. The refinery at Townsville, a wholly owned subsidiary of Mount Isa Mines, with an annual capacity recently expanded to 95,000 tons, is by far the larger of the two. It was commissioned in 1959 and refines the whole of the Mount Isa output. In 1971, 84% of the copper concentrates produced in Australia were domestically processed to blister or refined metal; the commissioning of a smelter at Tennant Creek in 1973 and additional production at Cobar (refined at Port Kembla) promise a rising level of processing.

In 1965, industrial trouble at Mount Isa affected mine production, and 90,000 tons of copper were mined in Australia. 1966 saw a rise of 24% to a record level of 110,000 tons; but continuation of K57 shaft development at Mount Isa again reduced the Australian output, to 90,000 tons in 1967, rising to 108,000 tons in 1968, to 129,000 tons in 1969, to 155,000 tons in 1970, and to 175,000 tons in 1971. Apparent consumption of primary copper in 1971 was 82,000 tons. The sources of production in 1971 are shown as follows.

		Tons (metal)
Queensland		
Mt Isa	112,852	
Mt Morgan	9,851	
Others	3,968	126,671
New South Wales		
Cobar	6,954	
Broken Hill	3,625	
Others	326	10,905
Tasmania (mainly Mt Lyell)		25,121
Western Australia (mainly Ravensthorpe)		2,851
South Australia		2,221
Northern Territory (mainly Peko)		6,676
Victoria		16
		174,461

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 separation of the lead from the zinc is then achieved by crushing and concentrating processes.

Since the discovery, in 1883, and the development of the Broken Hill orebody, perhaps the richest of any 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 1971 with a production of 397,000 tons we continue to rank as the fourth largest producer in the world behind USA, USSR, and Canada. 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 1960/61, when it was affected by an international arrangement under which a substantial part of Australian production was voluntarily curtailed.

Details of lead in all mine products from the States in 1970 are as follows:

		Tons
New South Wales		
All Broken Hill Mines	249,580	
Others	3,960	253,540
Queensland		
Mt Isa		127,254
Tasmania		
Read-Rosebery		16,355
Other States		33
Total		397,182

Most of our lead concentrates are smelted in Australia. There are smelters at Port Pirie, S.A., Mount Isa, Qld, and Cockle Creek, N.S.W., and a lead refinery at Port Pirie, which in 1971 produced 161,000 tons of primary refined lead. Exports amounted to 121,000 tons of refined lead, 162,000 tons of bullion (lead content) and 53,000 tons in concentrates (lead content). Domestic consumption was 62,000 tons (including 29,000 tons from scrap). The level of domestic processing of lead concentrates to bullion or to refined lead continues high and amounted to 84% in 1971.

The fall in lead prices in 1971 induced some voluntary cut backs in production so that the trend of increased production in recent years was halted in 1971.

Zinc: For a number of years Australia has ranked fourth behind Canada, the USA and USSR as the world's leading producers of zinc ores. Although domestic mine production increased by 8% to a record 400,000 tons in 1967, refined zinc output remained at the 1966 level of 194,000 tons, due to power restrictions in Tasmania. In 1968, mine production rose to 416,000 tons and, with the easing of power restrictions in Tasmania, refined zinc output increased to 205,000 tons to more than match the 1965 level of 199,000 tons. In 1969, mine production increased to 502,000 tons and refined zinc output to 242,000 tons, but in 1970 mine production slipped back to 480,000 tons although refined zinc further increased to 256,000 tons. Production was further reduced in 1971 by voluntary cut backs, by lower grades of ore, and by some industrial trouble to mine production of 445,000 tons and to refined output of 255,000 tons.

Details of 1971 production are as follows:

		Tons
New South Wales		
Broken Hill Mines	280,026	
Others	8,818	288,844
Tasmania		
Read-Rosebery		51,916
Queensland		
Mt Isa		104,737
Total		445,497

There are three zinc refineries in Australia - a large electrolytic plant at Risdon, Tasmania based on relatively cheap hydroelectric power; a small "Improved Vertical Furnace" at Cockle Creek, N.S.W., of a type developed within the last decade; and at Port Pirie, a new refinery to recover high-grade zinc from a slag dump estimated to contain 1 million tons of zinc derived from the treatment of lead concentrates, was commissioned in 1968. The plant has a rated capacity of about 40,000 tons of zinc per year.

About 50% of our total zinc concentrates (all from Tasmania, and some from Broken Hill) were treated at these plants. The remainder of the concentrates from Broken Hill and all of those from Mount Isa were exported. In 1971 production of refined zinc was 255,000 tons. Domestic consumption was about 111,000 tons of refined zinc of which 104,000 tons was of primary origin.

Tin: From being a country with a once considerable export surplus, Australia became partly dependent on imports about 1947; indeed Australia led the world in tin production for nearly a decade around 1883. Recent developments in 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 from 6,500 tons in 1968 to 8,100, the highest since 1913, and production increased further in 1970 to 8,700 tons and to 9,900 tons in 1971. Smelter production of refined tin has also risen since 1968 and in 1971 reached 6,200 tons. Imports were 129 tons of ingots, exports 3,300 tons tin in concentrates and 1,900 tons in ingots; and apparent consumption was 3800 tons of primary tin.

Domestic consumption rose sharply to about 4,500 tons following the commissioning of new electrolytic plant at Port Kembla in 1962, but has declined marginally in subsequent years following the swing to electrolytic tin-plating. Domestic consumption of primary tin increased marginally from 3763 tons in 1969 to 3800 tons in 1971 but is not expected to exceed 4,500 tons per annum in the immediate future, due to the swing towards lighter tin coatings; we are likely to remain a net exporter of tin in concentrates and in metal for many years ahead.

For some time past the main tin producing centres have been alluvial deposits inland from Cairns and in north eastern Tasmania. Lesser but useful production has come from lode mining in New South Wales, Western Australia, and Tasmania. Important new discoveries have been made in recent years at Renison Bell and Mount Cleveland, both on the western side of Tasmania, where drilling has revealed extensions of the old sulphide tin lodes. Both these properties are now in production, and at Cleveland mine a township has been built and a concentration mill was commissioned in 1968. Production at Renison rates the mine as a major tin producer even by world standards. At Greenbushes, W.A., a former alluvial field, modern equipment has been introduced to work lower grade ground previously left behind as unprofitable, but progress has been uncertain. Exploration in recent years has concentrated on proving additional reserves at established mines, rather than testing new areas.

Some of the greatest tin producing countries in the world, viz. Malaya, Thailand, and Indonesia, lie immediately to the north of Australia as our nearest sources of supply; much farther afield lie Nigerian and Bolivian deposits, but it would seem very unlikely that we could not supply our own needs in emergency in the foreseeable future.

URANIUM, THORIUM ETC.

Uranium: Australia is not a consumer of uranium although small quantities of uranium-derived fuels are imported for use in research at the atomic reactor at Lucas Heights near Sydney. A few years ago we passed through a brief but spectacular interlude as a producer of uranium ore and now appear to be on the threshold of becoming a more important producer. The national search for deposits began in 1944 and bore its first fruit in the discovery of Rum Jungle in 1949, and of Mary Kathleen in 1953. Some small deposits have been 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, N.T., in the early 1950's. 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 stockpiles ores until 1971, Mary Kathleen, now closed down on a care and maintenance basis, and Moline, N.T., which after fulfilling the last part of an overseas contract for uranium was modified to treat Ag-Pb-Zn ores from Mount Evelyn pending resumption of uranium mining.

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

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

On the other hand Rum Jungle has mined out both of its known orebodies and the plant continued to operate on stockpiled ore, and stockpiled the uranium oxide product, in a program that was completed in 1971. Several years ago it was announced that a total of 1,625 short tons of oxide had been produced during the life of the Rum Jungle plant and that total revenue over the period of operation has been $42 million. Mary Kathleen produced oxides worth $90 million but there has been no production since 1964.

Meanwhile, the easing of the total export embargo, announced by the Commonwealth Government in 1967, has stimulated prospecting for new reserves with notable success. New deposits have been found in the Westmoreland area, N.W. Queensland, deposits of sedimentary uranium are being assessed near Lake Frome and at other localities in South Australia, promising deposits at Yeelirrie in Western Australia are under assessment, and of prime importance are new and substantial deposits at the Ranger 1, Nabarlek, Koongarra, and other prospects about 230 km east of Darwin, in a new major uranium province in the Northern Territory. New figures for reserves of uranium ore, mineable at prices up to $10 per lb U_3O_8, must await the completion of current exploration programs, but the figure of about 18,000 short tons of U_3O_8 quoted in 1970 has increased many fold to at least 100,000 tons.

The marketing of uranium still faces difficulties because the demand for nuclear power is developing at a slower rate than was forecast; however, some overseas contracts have now been signed and demand will probably quicken later in the 70's.

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

Thorium and Cerium: The main commercial source of thorium, which has been of interest because of its possible nuclear uses, is in the mineral monazite, a by-product of beach sand operations on both east and west coasts of Australia. Notwithstanding the use of thorium in several United States experimental reactors, large scale nuclear uses in fast breeder reactors are said to be unlikely until after 1980; demand for nuclear purposes will probably not exceed a few hundred tons over the next 15 years. However, this situation could conceivably be changed as a result of new technology, or beneficiation and refining advances.

An increasing interest in monazite results from its rare-earth minerals content, two of which are cerium and yttrium. The rare-earths are used in the ceramics industry, in metal alloying and in nodulizing cast iron, and mixed oxides provide valued polishing media. Lately rare-earths have attracted increased interest because of their developing use in nuclear control rods, light amplification, cryogenic, thermo-electric, and electronic devices, as a superior red phosphor in colour television, as catalysts, and in many alloys for laser application. 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. In 1970 production was a record 4367 tons of concentrates containing about 3900 tons of monazite, 90% of which came from Western Australia; production of concentrates was only marginally less in 1971 at 4312 tons. Australian production amounts to about one half of total world supplies of monazite. Installed capacity for the recovery of high grade monazite near Bunbury, Western Australia is now about 3,500 tons and the plant is almost fully employed. 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 produce mixed rare-earth oxides, yttrium oxide, and thorium oxide from monazite; however, financial and market difficulties forced closure of the plant in 1972.

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

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

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 tons containing some 6.9 tons of beryllium oxide. However, the same year saw exports totalling 637 tons 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 15 tons of ore in 1968 and to 7 tons in 1969, but increased to 18 tons in 1970 and to 71 tons in 1971.

Most of the Australian production has come from a mine near Broken Hill, with some from the goldfield districts of Western Australia, although production in 1970 and 1971 came mainly from Western Australia. In time of emergency, particularly if production costs were not the principal consideration, the small scattered deposits already known could most likely produce sufficient for our foreseeable requirements. Overseas sources are Brazil, South Africa, Rhodesia, Uganda, the Congo, and the United States.

Lithium: The main uses are in the glass, ceramics, and pharmaceutical industries and in the preparation of greases and welding and brazing fluxes; as it seems particularly suitable as a battery anode material, and much interest in battery research was generated in recent years, a significant market could develop in the future. No detailed information is available on the consumption of lithium products in Australia but it is quite small and, except for occasional purchases from local production, requirements are usually imported. South Africa dominates the world production scene but Canada and the United States are alternative sources.

There has been an irregular production of lithium ores since 1905. In 1971 amounts totalling 1048 tons were produced in Western Australia.

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

OTHER METALS

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

A series of spectacular discoveries was to change this picture completely. They began in 1949 when relatively small deposits of bauxite were found at Marchinbar Island off the coast of Arnhem Land by the Bureau of Mineral Resources; this was followed by more substantial deposits on the mainland near Gove. Later, in 1956 very large deposits of bauxite were found at Weipa on the Cape York Peninsula by an exploration company; and in 1958 important new sources were identified at Jarrahdale, in the Darling Ranges close to Perth. Most recently, in 1965, an announcement was made of the discovery of further large deposits inland from Admiralty Gulf in the Kimberley district of Western Australia. In late 1970 exploration for possible bauxite deposits beneath the Gulf of Carpentaria, offshore from Weipa, commenced, although hitherto unsuccessful, and exploration on land south of the Weipa deposits was reported as indicating seven hundred million tons of bauxite, although the grade has not been specified. Production of ore from Weipa and Jarrahdale has mounted rapidly since 1962 and in 1971 reached 12.5 million tons. Australian reserves are now known to be very large, at least 4500 million tons, and almost certainly the largest of any country in the world.

On the industrial side, developments have also been rapid, and imports of alumina have been relatively low (17,000 tons in 1971) and used principally for purposes other than aluminium production since the commissioning of the Gladstone alumina refinery in 1967. The Bell Bay plant, owned by Comalco Industries Pty Ltd, has been expanded to a capacity of 94,000 tons of metal per year, and is being supplied with alumina from Gladstone derived from bauxite from Weipa where extensive mining and shipping facilities are installed. An alumina plant at Kwinana, near Fremantle, W.A., with a present capacity of some 1.25 million metric tons per annum, is supplying feed to the smelter at Geelong. Alcoa commissioned a second refinery at Pinjarra, W.A., in 1972, with an initial capacity of 210,000 tons of aluminia per year, for future expansion. The Geelong smelter of Alcoa of Australia Ltd came into production with an initial capacity of 20,000 tons of metal and was later expanded to 45,000 tons. Alumina is also being shipped from Kwinana to Japan and the United States.

The C.R.A. - Kaiser group, in partnership with several major overseas companies, constructed an alumina plant at Gladstone, Qld, with an output of some 900,000 tons of alumina per annum; this has now been expanded to 1,275,000 tons per annum. Part of this production is used as feed for a smelter at Bluff, New Zealand, completed in 1971 by Comalco in partnership with Showa Denko K.K. and Sumitomo Chemical Company. About half the Bell Bay alumina requirement will be provided by Gladstone; the bulk of Gladstone's output will be sold overseas but part will go to Newcastle, where Alcan Australia Ltd. established a primary smelter using coal as a source of power in 1969, with an initial production of 30,000 tons of metal which reached 45,000 tons per year in 1971.

Early in 1969 an agreement was completed between the Commonwealth Government and Swiss Aluminium and Australian partners for a project at Gove, N.T., to produce 1 million tons of alumina and up to 2 million tons of bauxite for export; initial shipments of bauxite began in June 1971 and the alumina refinery came on stream in June 1972. The current position in Australia therefore is, resources of bauxite of at least 4500 million tons and plant capacity for the production of 2.5 million tons of alumina and of 234,000 tons of aluminium with further expansions in train or planned. However, conditions of over-supply, evident in world markets in late 1971, have been countered by cut-backs in the production of both alumina and metal in Australia in 1972.

<u>Antimony</u>: Antimony is used principally to impart hardness and stiffness in lead alloys, as an ingredient in type metal, Babbit metal, Britannia metal, pewter, and in the plastics industry.

Domestic production of antimony in antimony concentrates in 1971 was 694 tons, nearly all of which was exported. In addition 646 tons of antimony from Broken Hill concentrates was contained in antimony alloys produced at Port Pirie. All told, over 13000 tons of antimonial lead and other alloys were produced in 1971, containing 685 tons of antimony of which about 40% came from lead scrap.

Exports of antimonial lead alloy in 1971, mainly to Japan, amounted to 4000 tons. No antimony metal was produced in Australia in 1971 and only 29 tons were imported; Mainland China remains the chief supplier.

Antimony ores have been produced in Australia since the middle of the last century but most deposits have been worked out. Recently the only significant production has come from a mine at Guyra in north-eastern N.S.W. - 1971 production was 102 tons of antimony in concentrates. This mine closed in late 1971 but one near Kempsey is in production and at another near Domgo production awaits higher prices.

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

Titanium: Australia's resources of titanium minerals (rutile and ilmenite) are considerable. In 1971 our production of rutile concentrates was a record 369,000 tons, which represented over 90% of the world production; and of ilmenite concentrates 815,000 tons, which held our position as second below Canada in the list of principal western producers.

The traditional uses of rutile have been in the manufacture of welding rods and the production of titanium metal; more recently by virtue of the chloride method of processing, it has come into use in the manufacture of pigment for high-gloss white paint. Ilmenite usage is largely confined to pigment, which is held in only a little less esteem than the rutile product. However, the commercial application of processes by which ilmenite is up-graded to approach rutile in TiO_2 content (beneficiated ilmenite or synthetic rutile) will provide a feed for either pigment or metal via the chloride process; beneficiated ilmenite is likely to become a competitor or substitute for natural rutile by the mid 1970's.

The principal Australian resources of rutile are sands on and adjacent to the beaches of the eastern coast, although at current levels of production reserves seem limited to 15-18 years. Production is principally sustained by long-term contracts with the United States. However, discovery in 1971 of old shoreline deposits of rutile, zircon, and ilmenite near Eneabba, 280 km north of Perth, promise some additional supply of rutile. World demand for rutile has been rising rapidly up to 1971 but our production is not likely to rise much beyond 350,000 to 400,000 tons of concentrates per year. 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; however, a major new ilmenite project on low-chrome deposits near Gladstone, Qld, from which production of synthetic rutile is eventually planned, commenced production in 1969, although production ceased, probably temporarily, in 1970.

The principal ilmenite industry has been built up along the south western 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 growing industry. By-products of ilmenite mining are monazite, zircon, and rutile. A beneficiation plant at Capel, W.A. was commissioned in 1968 by Western Titanium Ltd. The plant has operated on a semi-commercial scale to date but an increasing proportion of ilmenite is expected to be processed for export in the future and the plant is now being extended to produce 40,000 tons of upgraded ilmenite per year. A TiO_2 pigment plant was commissioned several years ago at Bunbury, W.A., based on local supplies of ilmenite. Ilmenite is shipped to Burnie (Tas.), where a pigment plant has been operating since 1949. Ilmenite concentrates are exported from Bunbury, where substantial bulk loading facilities have been brought into operation.

Zirconium: Australian resources of this metal, in the beach sand mineral zircon, are considerable and are of the same order as those of rutile. Mining operations on the eastern and western coasts yield zircon as a co-product or by-product respectively. The market for zircon, principally required for foundries in the form of moulds, facings and cores, faced oversupply in 1970 but is expected to firm in 1973 or 4; 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. In 1971 production of zircon concentrates was 406,000 tons - the largest of any country in the world. Almost the entire output was exported. However, it should be noted that slow-downs in economies, particularly in U.S.A. and Japan, in late 1971 have reduced spot sales of all beach sand minerals and it will probably be a year or so before normal growth rates resume.

Australia's reserves of beach sands render her self-sufficient in these minerals, and particularly in ilmenite, for many years to come.

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

In 1971, mine production of cobalt totalled 783 tons, of which 103 tons were contained in zinc concentrates from Broken Hill, N.S.W., and 680 tons in nickel concentrates produced in Western Australia; however, only a small proportion is recovered in Australia. The zinc refinery at Risdon, Tasmania, which continues to be the major supplier of cobalt for Australian industry, produced 30 tons of cobalt oxide (21 tons of cobalt) from zinc concentrates in 1971 - about a tenth of Australian requirements. A nickel-cobalt sulphide product is obtained from the nickel refinery in Perth as a by-product and additional cobalt-bearing products will be produced by the proposed nickel smelter at Kambalda and from the proposed nickel refinery at Townsville; but these products are likely to be exported rather than further refined in Australia in the immediate future. These by products would probably 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 Congo (the world's principal producer) Canada, Morocco, and Zambia. The U.S.A. is an alternative source from which imports are also obtained.

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

Production of refined cadmium in 1971 was 551 tons of metal; 342 tons came from Risdon, 189 tons from Cockle Creek, and 20 tons from Port Pirie. Mine production was 1464 tons. Domestic sales in 1971 were about 69 tons and the rest was exported, including cadmium contained in lead-zinc concentrates. Australia is more than self-sufficient in this metal but United States, Canada, and Japan are alternative sources.

Tantalum-Columbium: Tantalum and columbium 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 small levels. In Western Australia there is commonly a small annual output, mainly as a by-product of tin mining. This amounted to about 74 tons of combined concentrates in 1971; and was all exported. There is no domestic demand but if one arose in time of emergency it is most likely that some of the known deposits could be reopened to provide the requirement.

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

Gold: Annual production, once steady at above 1 million ounces, has been falling slowly for a number of years. In 1970 reflecting the difficulties confronting the gold mining industry, production fell to 620,000 oz, of which 58 percent came from gold mines in Western Australia, with a very minor contribution from gold mines in Victoria. The remainder (42% of production) came from base metal mines, principally copper mines, in the Northern Territory, Queensland, Tasmania, and New South Wales, where gold is a valuable by-product. However, slowly rising gold prices in 1971 reserved the trend and production rose to 672,000 fine oz. The major disability suffered by the gold mining industry is that whereas the price of gold has been fixed for more than 30 years, the cost of production has mounted steadily. In order to keep marginal mines in operation and to maintain existing communities in a number of isolated places, the Commonwealth Government has introduced various forms of assistance including a subsidy on production which was extended to 30th June 1973 in 1970 and increased in 1971. Gold's main use is as a dollar earner, with a world price of $US35 per troy oz. However, in 1968 the International Monetary Fund agreed to a two-tier system under which gold might be traded at higher than the official price; in general, this system together with other measures has induced a fairly stable free market for gold which increased notably to about US$60 per troy oz. at the end of 1972, promising some rejuvenation of gold mining.

Silver: All Australian silver is won as a by-product from mining other metals, more particularly lead and zinc. Mine production in 1971 was 22.0 million ounces, most of which came from the lead-zinc industry. Silver refined in Australia in 1971 was 8.4 million ounces and almost all the rest of the mine product was exported in concentrates or bullion.

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, New South Wales, and Papua New Guinea, but very little production has been recorded from them since 1968; however, interest is resuming in the Adamsfield area of Tasmania and the West Sepik district of New Guinea. A small amount is commonly recovered annually as a by-product of gold refining at Port Kembla, but no output was recorded in 1971; however, 80 ounces were recovered from copper concentrates in Victoria. Platinum will be recovered from nickel ore in Western Australia when smelting of concentrates begins in 1973; it is not recovered at the nickel refinery at Kwinana. In 1970, 1643 troy ounces of platinum group metals were contained in, and realised from nickel concentrates from Kambalda exported to Japan. Platinum ore was reported from the Pilbara region, W.A., in 1970 but is still under investigation.

Imports in 1971 amounted to 30,000 troy oz and some 10,000 oz., were exported. Canada and South Africa are among the world's leading producers and overseas demand was strong. Both producer and free market prices, stable in 1969, have since declined as a result of current world over-supply; but future increased demand in the control of air pollution from motor vehicles should again stabilize the situation.

Selenium and Tellurium: Selenium is used in small quantities in the electronic, chemical, glass, and metallurgical industries but is being replaced in some of its uses with the cheaper materials silicon and germanium. There is some production from tankhouse slimes containing 0.33% selenium in the electrolytic copper refineries at Port Kembla but no statistics are available. However, neither production nor domestic consumption is large. Leading overseas producers are the U.S., Canada, and Japan.

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

Bismuth: There has commonly been a small annual production of concentrates of this metal as a by-product of tin and tungsten concentrates from the Northern Territory and Western Australia. In 1967, the Juno gold mine at Tennant Creek recorded the first production since 1962. Production in 1971 was a record 252 tons of bismuth contained in 1563 tons of concentrates produced at Tennant Creek, with small contributions from Wolfram Camp and Biggenden in Queensland. Concentrates produced at Tennant Creek are currently exported but a flash smelter at present under construction at Tennant Creek will convert copper concentrates to blister copper and recover bismuth for conversion to crude bismuth bullion, commencing in 1973. Imports have dwindled since 1965, when a world scarcity developed, and subsititutes were developed for some uses. Present uses are for low melting point alloys and for the production of salts used in the pharmaceutical and chemical industries. Chief sources are the United Kingdom, Peru, Mexico, Canada, and Japan.

Mercury: Australian reserves are negligible, but mercury was produced early in 1967 for the first time since 1945. In 1971, 665 lb were recovered as a by-product from the treatment of Rosebery ores at Risdon. The metal has lately been finding increasing use in the electronic industries and in 1971 some 80,000 lbs were imported from Mexico, Spain, U.S.A. and Japan. World production during 1971 was some 21 million lbs.

Vanadium: This metal, used in both ferrous and non-ferrous alloys, and in the chemical industry, is a common constituent of minerals but is rare in economic deposits. None has been produced in Australia and local consumption is negligible, but recent exploration has indicated possible 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 South west Africa. Western world production in 1971 was about 9,600 tons.

Indium: 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 are no production or known reserves. It can be obtained from Canada, the United States, Belgium, Western Germany, or Japan.

NON-METALS

Abrasives: 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 approached 700,000 carats in 1971 but with a significant re-export trade. The Union of South Africa is the world's major producer, followed by other African countries, and in recent years there has been some uneconomic production from off-shore dredging along the West African coast. Some interest has been expressed from time to time in the possibility of diamond deposits in Australia; at present at least one company is active in Western Australia - but so far without discovery. Corundum and emery have been mined on a small scale in Western Australia but there is now no domestic production, and imports commonly amount to about 2000 tons (1671 tons in 1971), mainly for use in optical polishing. Rhodesia is the world's leading producer, followed by India, South Africa, and USSR.

More than 50% of our requirement of garnet is normally obtained as a by-product of mining beach sands along the eastern coast: imports, almost exclusively from the U.S.A., fulfil the remainder of our requirements. Sales of garnet concentrates totalled 508 tons in 1971.

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

Arsenic: Used in insecticides, sheep dips, weed killers, wood preservatives, and in glasses and enamels, arsenic is now all imported (1265 tons in 1971). A considerable amount was at one time obtained as a by-product from gold mining at Wiluna, W.A., 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 principal world producers are Sweden, Mexico, and France.

Asbestos: Australia has large resources of blue asbestos (crocidolite) in the Hamersley Range, W.A.; but to date few deposits of amosite and of white asbestos (chrysotile). Because of its fineness, strength, flexibility, and suitability for spinning fibres, white asbestos is the most valuable variety. One deposit at Baryulgil, N.S.W., which has been exploited for some years, produced 924 short tons in 1971, and 57 short tons of fibre were produced from old dumps at the Lionel Mine in the Pilbara district of Western Australia, giving total production in 1971 of 981 short tons. However, another chrysotile deposit at Woodsreef near Barraba, N.S.W., reported to contain over 18 million tons of fibre-bearing rock, has recently been developed and came into production in January 1972; output in 1972 was about 23,000 short tons of fibre (exports about 10,000 tons) and this is expected to rise to about 70,000 short tons in 1973 of which some 67,000 tons are likely to be exported. The product is dominantly short fibre and although this satisfies local demand for this type and provides exports to Japan, imports of longer fibre chrysotile and of amosite asbestos will remain significant. Imports in 1971 were 48,000 tons of chrysotile, 11,000 tons of amosite and 14,000 of other varieties, mainly chrysotile fines.

Blue asbestos, which lacks many of the desirable properties of the white, but is stronger and more resistant to chemical action, continues to be used in some parts of the world in the manufacture of asbestos cement products such as building sheets, pipes, guttering, etc. Extensive deposits exist near Wittenoom, W.A., which were worked till 1966, producing 13,000 tons in that year mainly for export, but production has since ceased because of rising costs.

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

Barite: Australia has adequate resources of this mineral, the principal use of which is in oil drilling muds, and lesser uses in paints, chemicals, and paper manufacture. Production can probably be increased to meet any future domestic requirement but in recent years it has fluctuated widely because of the varying demand by oil drilling. Since 1967, there has been a steady demand by secondary industry and production increased to about 42,000 tons in 1970, mainly due to an increased demand for drilling muds in off-shore drilling and to increased export sales. Production increased to 53,000 tons in 1971 although exports fell to 16,000 tons reflecting a decline in oil drilling activity. 3,000 tons of barium chemicals were imported in 1971.

Bentonite and Fuller's Earth: The demand for bentonite has risen sharply since 1967 because of increased need for drilling mud, in iron ore pelletizing, and the steady demands of foundries. The rise has been met by expanded imports. An important use continues to be as a bonding agent for moulding sands. Local production of bentonite in 1970 was 283 tons (compared with 352 in 1970) and imports 87,000 tons; 90 tons of Fuller's earth were produced in 1971. Recently, during regional geological mapping, extensive seams of bentonitic clays were discovered in the Carnarvon Gorge in Queensland and a great deal of testing has been going on to decide their economic worth. Testing of deposits of bentonite in other States is also taking place and it is possible that Australian production may rise substantially in the future. The United States and Italy are the main world producers of the high quality bentonites, which are in heavy demand for drilling muds.

Diatomite: There are many small deposits of this mineral in Australia, which consumes some 8-9,000 tons annually. Production has been almost continuous since 1896, and amounted to some 900 tons in 1971, the shortfall being met from imports. Diatomite is extensively used in filtration processes in the manufacture of foods and beverages, as an insulating medium in furnaces and boilers, and as a light-weight filler for paints, varnishes, and synthetic plastics. The Australian product is not entirely suitable for filtering processes and some 6,800 tons were imported mainly from U.S.A. in 1971. Resources for other purposes are adequate.

Feldspar: Uses are mainly in the glass and ceramics industries and as an abrasive. Australian resources are large and more than enough for any likely requirement. Present centres of production are Londonderry, W.A., Broken Hill and Duckmoloi, N.S.W., for the potash varieties; and Gumeracha, S.A., for the soda varieties. 1971 production was 3200 tons. This could be expanded almost at will, but consumption has declined owing to the greater suitability of nepheline for some applications.

Fluorspar: This mineral is used in steel production, in foundries, in the smelting of aluminium, and in chemicals, glass, and ceramics. Australia has never been a large producer and the extent of her resources is not known. In recent years local production declined to nil in 1963 because of the ready availability of high quality material from overseas at a low price. However, some production began at Walwa in Victoria in 1970 (1,250 tons) with reduced production of 457 tons in 1971. Imports have mounted steadily and in 1971 were 32,000 tons, mainly from South Africa and United Kingdom and China. France, Italy, and the United States and Mexico are also important world producers. Increasing Australian and world demand for fluorspar has induced considerable prospecting activity in most Australian states; promising prospects are under investigation in Central Australia and the Kimberleys in W.A. and it is hoped that additional production for both domestic demand and export will result.

Graphite: This mineral has extensive uses as a lubricant, and is employed in many manufacturing processes, for moulding, for graphite crucibles, and in lead pencils. Local production is minor and so far no high-grade deposits have been discovered in Australia, although possible resources have not been fully investigated. All our requirements are met by imports, which amounted to some 1600 tons in 1971 mainly from Ceylon, Mainland China, and Malagasy; Korea, Austria, Mexico, and Germany are also important world producers.

Gypsum: Australia's resources are very large indeed, known reserves being in excess of 760 million tons with the probability of a great deal more. The deposits are associated with salt lakes and occur in the drier parts of South Australia, Victoria, New South Wales and Western Australia. The chief use is in the manufacture of plaster, cement, and products such as building boards. In 1971 production amounted to 875,000 tons, of which 250,000 tons were exported.

Limestone, Dolomite and Magnesite: These have been referred to earlier in connection with metals magnesium and calcium. Resources are very large and production could be increased indefinitely. In 1971 limestone production was 10 million tons and dolomite production was 361,000 tons. Production of both could be increased almost at will. Magnesite production was 18,000 tons.

Mica: Although Australia's resources are probably large, her production, in the face of cheap overseas supplies, has virtually ceased. The main fields, in the Harts Range in central Northern Territory, now support only a few fossickers.

While the Commonwealth Mica Pool operated, during and after the war years, a series of small mines in this locality produced most of our requirement. With the winding up of the Mica Pool in 1960, the market disappeared and most of the small recent production has been from scrap from dumps. Imports in 1971 amounted to about 1100 tons mainly from India, South Africa, and the United Kingdom and Norway. In the event of emergency Brazil, Argentine, and Malagasy are possible sources, but Australia's own domestic industry could probably be revived to meet her requirements.

Pigments and Ochres: The term is here used to mean natural earth pigments such as the iron oxides, stained clays, and slate powder which are used to give colour or body to paints, plaster, cements, linoleum, and rubber. A number of small deposits have been worked over the years and Australia undoubtedly has large resources of the iron oxide variety. Some of these are at Wilgie Mia and Weld Range, W.A., Rumbalara, N.T.; Dubbo and Glen Innes, N.S.W.; and Peason, Spalford, and Deep Creek in Tasmania. Domestic consumption is very small and production in 1971 amounted to about 70 tons, most of which came from Western Australia. Some 8770 tons were imported in 1971/72, while 35 tons were exported.

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 no better success. The last recorded Australian production was in 1952 from an occurrence near Glen Innes. Imports of quartzite and natural quartz amounted to 984 tons in 1971/72. Recent developments overseas in synthesizing quartz crystal have eased pressures on the need to discover indigenous sources. Some 161,000 tons of high-grade silica sand were exported to Japan in 1971, mainly from deposits recently discovered near Cape Flattery, North Queensland.

Salt and Sodium Compounds: Common salt, sodium chloride, can be produced abundantly in certain climatic localities in Australia, either by the evaporation of sea-water or by harvesting the annual deposits from salt lakes and pans in the drier parts of the continent. Production has been growing in recent years as a worthwhile export trade has been built up. South Australia contributed about 70% of the 900,000 tons produced in 1968 but Western Australia produced about half of the total of 1.7 million tons in 1969, 60-70% of the 3.0 million tons in 1970 and 75% of the 3.7 million tons produced in 1971. New developments include a seawater project at Shark Bay, W.A., with a planned output of 1.0 million tons p.a., most of which will be exported to Japan, and an underground brine evaporator at Port Alma, Qld, which finally might produce 450,000 tons p.a., to supply a chlorine-caustic soda plant at Botany Bay. Seven hundred acres of land have been released for salt production near Rockhampton, and seawater projects at Port Hedland (1.8 million tons p.a.), Dampier (1.5 million tons p.a.), Lake Lefroy (800,000 tons p.a.) and Lake McLeod are in operation. In the event of these new projects being fully developed Australia's salt production could reach over 8 million tons by 1975; indeed sluggish markets, mainly in Japan, caused problems of over-production in 1972 and downward revision of production targets is necessary.

In recent years several oil wells in the central and northern parts of Australia have revealed large subterranean masses of salt, a type of occurrence well-known in oilfields abroad, some of which are sources of both common salt and potash. Regional geological mapping has indicated the likely positions of several more. These could offer interesting possibilities if necessity arose but their geographical isolation is such that there seems little likelihood of commercial development at the present time, particularly because investigation so far has not indicated the presence of potash. Sodium compound production does not yet fulfil the home demand.

Sillimanite and Kyanite: These minerals are consumed chiefly in the manufacture of high-alumina refractory linings used in furnaces. Deposits of sillimanite are known in several parts of Australia, mostly in remote localities and are being worked in N.S.W. and S.A. Production was on the increase in recent years to meet increasing demands from industry but fell sharply, after a peak of 3,500 tons in 1963, to 2,600 tons in 1964. Production in 1971 was 843 tons and imports were negligible. However, 955 tons of kyanite were imported, mainly from India, and none produced locally.

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.

Sulphur-bearing materials: Consumption of sulphur in Australia, almost all of which is used as sulphuric acid, steadily increased up to 1967, when a record 1.99 million mono-tons were consumed. Consumption has decreased marginally since then as a reflection of drought years and decreased use of fertilizers. Production of acid was 1.84 million mono-tons in 1969, but fell to 1.65 in 1970 and to 1.62 in 1971. Some 46% of the acid was produced from indigenous sources in 1971 with the remaining 54% coming from imported elemental sulphur.

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

Sulphuric acid is currently produced direct from sinter gases from the treatment of lead concentrates at Port Pirie and Cockle Creek; and from zinc concentrates at Cockle Creek and Risdon. Pyrite concentrates are produced as a by-product from copper and gold treatment plants at Mount Lyell, Mount Morgan and Kalgoorlie and from lead-zinc mining at Read-Rosebery; pyrite from Mount Lyell and from Read-Rosebery is railed to an acid plant at Burnie, Tasmania. Production of pyrite from Nairne, S.A., ceased in 1972. These pyrite concentrates are used domestically for acid manufacture, except for those produced at Mount Morgan, which are used in the steel and glass industries. Sulphur is also recovered from oil refinery processes at Altona, Victoria, Port Stanvac, S.A., Clyde, N.S.W., and Bulwer Island, Qld. Alkylation sludges and hydrogen sulphide from some oil refineries or spent oxide from gas works are used in sulphur production.

Imports of elemental sulphur were 549,000 tons in 1968, but fell to 384,000 tons in 1969, to 320,000 tons in 1970, and to 264,000 tons in 1971. Canada and U.S.A. were the main source of supply. The non-Communist World production of sulphur in all forms in 1971 was 29.7 million tons of which 63% was elemental sulphur. World shortage of elemental sulphur in recent years has eased and the price is steadily falling, indicating no shortage of sulphur in the foreseeable future. Australia should continue to produce 40-50% of required acid as the new acid plant at Burnie (Tas) achieves full production. The Bureau of Mineral Resources has placed some emphasis on the search for elemental sulphur in sedimentary basins, where, to date, insufficient exploration has been carried out to properly assess prospects, but prospective over-supply of sulphur in the world this decade, increased by higher levels of recovery of sulphur from smelters to counter pollution, is discouraging exploration in Australia.

Talc, Steatite, and Pyrophyllite: The chief consuming industies are cosmetics, rubber, ceramics, and paint. Small deposits are known in most of the States and, in recent years, South Australia and Western Australia have been the chief producers. Production in 1971 amounted to some 50,000 tons of which 32,000 tons were exported. Imports, mainly of varieties not available domestically, were 4,000 tons. The United States and Japan are the world's leading producers, but Australian imports have come from Mainland China, United States, and India, as well as Italy and Norway.

Vermiculite: This mineral has the unusual property of expanding to many times its original volume when subject to high temperatures and is used for fire and rot-proofing, as an insulator in electrical and heating equipment, in the manufacture of building plaster, and as a light weight concrete aggregate. There was no production in Australia between 1956 and 1969, but several deposits are known to exist in Western Australia and 300 tons were produced in 1970 and 54 tons in 1971. A small amount is imported annually (about 7000 tons in 1971), usually from South Africa. The United States and South Africa supply almost the entire world production.

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

Phosphate Rock: is used in large quantities for the production of superphosphate (1.9 million tons in 1971, almost all of which was imported). Local sources capable of present production are almost negligible and are mostly unsuitable for superphosphate manufacture.

Australia's supplies of phosphate rock are drawn chiefly from Nauru and Gilbert and Ellice Islands in the Pacific, and from Christmas Island in the Indian Ocean. Christmas Island is owned jointly by Australia and New Zealand; Nauru is now independent but New Zealand, Australia, and United Kingdom are partners in agreements to share production from Nauru and from Gilbert and Ellice Islands. These supplies have been supplemented for many years from other overseas sources, mainly U.S.A. and North Africa, but with the consistant fall in consumption in Australia since 1968, stemming from drought and depressed rural conditions, imports from other overseas sources fell to 10 tons in 1971. Although the rock from the island sources is extremely high-grade by world standards, the deposits have limited life - approximately to the end of this century. Some years ago a widespread search for additional island deposits was made jointly by the Australian and New Zealand Governments, but no discoveries of importance resulted. It was therefore accepted that the chances of finding any new deposits of island phosphate to supplement the existing supplies were small and emphasis was placed on exploration within Australia in late 1964.

Small quantities of domestic phosphate rock have been mined intermittently in Australia for many years and have mostly been used for direct application as a fertilizer. South Australia was the only producer with an output of 7,000 tons in 1971. A discovery made near Rum Jungle in 1961 of an unusual type of phosphate deposit in ancient Precambrian rocks has been tested extensively by drilling and pitting. However, the proven reserve is only about 5 million tons of which 1 million has P_2O_5 content ranging from 20-27% and the rest is low grade. However, the higher grade material is too refractory to constitute an economic source for the manufacture of superphosphate, although the deposit may yet be useful locally as the material, when calcined, is suitable for direct application to the ground. Thin beds of phosphate rock were also found in the Amadeus Basin in the Alice Springs region in 1963 but these proved un-economic.

In 1964 Commonwealth and State Governments encouraged mineral exploration companies to search for phosphate and this resulted in much increased activity on the Australian continent. About the same time, the Bureau of Mineral Resources arranged for two overseas specialists to assess the phosphate potential of the Australian continent and also possibilities offshore. Recommendations on the continent emphasized eastern Australia and north west Queensland, and a study by B.M.R. of some of the oil wells which had been drilled in the Georgina Basin indicated abnormally high phosphate content in some formations. Further systematic testing of oil wells by companies led to the delineation of the most favourable formation and this in turn to the discovery of phosphate rock about 50 km south of Duchess in 1966. Continued exploration discovered similar but smaller deposits in the Yelvertoft area about 250 km north of Duchess and additional subsurface deposits in the Barkley Tablelands, N.T; drilling and assessment have now proved major deposits of phosphate rock in north west Queensland with reserves of at least 2000 million tons averaging about 17% P_2O_5 (with considerable tonnages of 20-22% material) and for the most part capable of upgrading to produce source material for superphosphate. These deposits assure Australia's supplies of phosphate rock in the long term and should lead to a significant export trade, principally to Asia. Feasibility studies are continuing to determine when any of these deposits can be profitably brought into production, and with the prospect of both domestic and world demand resuming an upward trend, this might well be before 1980.

Potash: All Australian requirements of potash salt are imported. In 1971 Australia imported some 145,000 tons of potash fertilizers and potash salts for chemical purposes. Half of this came from the U.S.A.; West Germany, Canada, and France are other important sources.

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

At Lake Chandler in Western Australia an effort was made at the end of the war to produce commercial potash from an estimated 12 million tons of mud with a content of 60 percent alunite, a potassium-aluminium mineral. The State Government sponsored this attempt, and a plant was erected which for a while attained a production rate of 1,000 tons a year; the operation proved uneconomic and the plant was closed in 1949. However a company is at present developing a project at Lake McLeod, W.A., with current production of salt and planned production of potash, the latter intended in 1973 with initial output of 80,000 tons per year. Salt domes inland from Shark Bay, W.A., were also explored for potash but with no encouraging results.

Nitrates: A significant growth trend is developing in the use of nitrogenous fertilizers which seems likely to change the accepted Australian pattern. The emphasis on ammonium sulphate is being diminished and nitrogenous phosphates are coming into demand. Several sorts of nitrogenous compounds are now produced domestically including ammonium phosphate, sulphate, and nitrate; urea; ammonia; etc. Statistics for some of these are not available for publication but production figures for sulphate of ammonia in 1970/71 were 174,000 tons, and about 34,000 tons of nitrogenous fertilizers were imported mainly from U.S.A. and Canada.

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

Petroleum: Australia's main mineral deficiency has long been that of indigenous petroleum, the lack of which has compelled her to import an ever growing volume of crude oils and refined products to meet her increasing consumption. In 1971 the value of imports of refinery feedstock and refined products fell to $118 million from $162 million in 1970 as a result of increased production from Bass Strait; indigenous crude oil amounted to about 60% of demand with the percentage expected to rise to about 65% in 1972 and fall to about 62% in 1973. The rate of increase in consumption was 5.9% over the previous year but demand is expected to almost double in the next 10 years.

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 7.6 million barrels; an increase of 124% brought about mainly by Barrow Island coming into production. This represented 5.1% of consumption as compared to 2.7% in 1966. In 1968, Australian indigenous production was 13.8 million barrels, in 1969, 15.8 million barrels, or 8.8% of total petroleum consumption, and 65.1 million barrels in 1970. Production rose rapidly to 112.9 million barrels in 1971 as the Gippsland Shelf fields came on stream.

Since the mid 1950's an Australia-wide search has been going on, with mounting intensity in recent years. In 1966 some 134 wells were drilled (compared with 14 in 1959); in 1967 the number rose to 274; in 1968 the total was 232; in 1969 the number of wells completed was 322, falling to 218 in 1970 and to 108 in 1971.

Part of the reason for the increasing tempo of oil search in Australia, particularly in the 60's, undoubtedly derived from the Commonwealth's policy of subsidizing private companies' expenditure under a scheme first introduced in 1958, extended to June 1969 and again extended to June 1974. Under this scheme selected operations were at first reimbursed by 50 percent (later reduced to 30 percent) of the cost.

Incentive has been 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 (and the nearby Toolachee) gas fields in South Australia, now supplying Adelaide with natural gas: the Gippsland Shelf major gas/oilfields Barracouta and Marlin supplying Melbourne, and the Dongara field in W.A. now supplying Perth. Other gas fields which have not yet been exploited are Mereenie - Palm Valley in the Northern Territory and fields on the North West Shelf off Western Australia. Other considerable gas discoveries have been at Uramu, Pasca (offshore Papua), and Bwata, Iehi, Barikewa, Kuru and Puri (onshore Papua). Gas has also been discovered in the Petrel well, 150 km west of Darwin, and major discoveries of natural gas are being explored on the Northwest Shelf off Port Hedland.

Crude oil was discovered at Moonie and Alton in Queensland, and these fields have been producing since 1964. Following this, the Barrow Island oilfield discovery in Western Australia began commercial production in December 1966. The most prolific crude oil discoveries were the Kingfish, Halibut, Marlin, and Barracouta fields in the Gippsland Shelf, and commercial production began from Barracouta in late 1969.

Other significant discoveries which have yet to be developed are the Snapper, Flounder, and Tuna fields, also situated on the Gippsland Shelf.

The Commonwealth also contributes to exploration activities in Australia by carrying out extensive geophysical surveys and geological mapping programs over sedimentary basins.

At the present time exploration permits are held over the surface areas of most of our known sedimentary basins and drilling has been going on in all States and Territories. Of late, the chief focus of interest has turned to the offshore localities, where extensive sedimentary basins exist under the shallow waters of the continental shelves. Drilling offshore is a more expensive operation than drilling on land, but the prospects are considered good. The first offshore rig, Glomar III, a drilling ship, was brought to Australia in 1964 at a cost of $2 million. With its first well, now named Barracouta, some 50 km from the Gippsland coast of Victoria, it discovered gas of considerable significance.

The same drilling unit discovered the Marlin gas field shortly afterwards, and the major Kingfish and Halibut oilfields in rapid succession, followed by hydrocarbon encounters in the Tuna, Bream, Flounder, Mackerel, and Snapper structures.

Production of crude oil and gas from this prolific area began in 1969, and by the end of 1971, crude oil production was some 345,000 barrels per day. Natural gas production from this area also began in 1969 and was some 280 million cubic feet per day in December 1971.

Further offshore drilling units arrived in Australia, and by mid-1969, six mobile units were operating in Australian coastal waters. Three of these units were drilling ships, two were semi-submersible platforms and one was a jack-up unit. In early 1970 five units were operating, and one was idle. However, only 4 offshore rigs were operating in early 1971, 5 in early 1972, and 6 in early 1973, emphasing the urgent need for further discovery, particularly of oil, offshore to encourage continued exploration.

In early 1972, some 328 wells were producing from the Barrow Island field, and total daily production was around 43,000 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 Dutsun to Dandenong commenced delivery to Melbourne and its environs in early 1969, and is currently delivering about 100 million cubic feet per day, eventually to rise to 200 million cubic feet per day.

Brisbane received its first delivery of natural gas from the Roma area in March 1969 through the 10 3/4 inch, 410 km pipeline. Production from this area will be sustained at a daily rate of some 20 million cubic feet per day.

In late 1969, Adelaide received natural gas through the 22 inch 778 km pipeline from the Gidgealpa - Moomba field. Production through this line reached some 100 million cubic feet per day in 1970. Natural gas was delivered to the Perth area from the Dongara field in October 1971 and arrangements are in hand to pipe natural gas to Sydney from the Cooper Basin in South Australia.

In 1972 indigenous crude oil production from proven fields supplied about 65% 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 importation 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 is increasing at about 7% per year, further substantial Australian discoveries are essential in order to maintain or reduce the deficit gap between indigenous production and importation. Should we not be successful in establishing additional petroleum reserves within our own boundaries, it will be necessary to turn our thoughts to other and less convenient source materials for fuel, and to other sources of power such as uranium. Petroleum can be distilled from oil shale, and considerable attention is now being directed to our shale deposits, particularly those in Queensland; on the other hand our very extensive resources of coal may provide an alternative source if economic methods of synthesis can be developed to suit them. A great deal of attention has been given, for several years, to setting up the research facilities necessary to examine all possibilities connected with making full use of our coal, and a good deal more is being done in this regard than is generally realized. The U.S.A. has already advanced far, both in research and applied technology, in this field.

<u>The Role of Government in Assisting Mineral Exploration and Development</u>: One of the prime needs for any systematic search for minerals by modern methods is for adequate base maps - topographic, geological, and geophysical. It is by provision of these maps, as well as geological and geophysical services generally, that Government makes its main contribution to the search.

It is perhaps not generally known how much effort goes into the mapping programme, or how far it has already advanced. The Department of Minerals and Energy provides a focus for the various Government agencies engaged in this widespread and important activity. Overall direction of the topographic programme is provided by the Department but its activities and those of other Commonwealth mapping agencies are subject to annual review by an Advisory Committee on Commonwealth Mapping, chaired by the Secretary of the Department and comprising representatives of the Navy, the Army, the Department of the Interior, and the Institution of Surveyors. A second body, the National Mapping Council, consisting of the Director of National Mapping (Chairman) and the Surveyors-General of the States and Commonwealth, is a high-level technical body which coordinates State and Commonwealth programs.

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

Both Commonwealth and State agencies undertake regional geological mapping. Programs are agreed upon in consultation between the Bureau of Mineral Resources and the State Geological Surveys, but the work is necessarily a good deal slower than that of topographical mapping and the time required to complete a similar 1:250 000 coverage of the continent will be several times as long at least. However, over 80% of the continent has been covered since World War II.

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

Generally speaking there is very satisfactory co-operation in mineral exploration between the Commonwealth, the States, and private industry. Programs of work involving contributions of men or equipment from all three sources are not unusual. One common type of arrangement is for Government agencies to carry out geological and geophysical surveys after a prior understanding that the companies will embark upon any subsequent testing that appears warranted.

Other direct contributions to mineral search are made by the Commonwealth in the form of bounties and subsidies. Examples are bounties on the production of gold, and subsidies toward the cost of oil exploration. 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.

On occasions, particular minerals have been given specifically favourable taxation treatment when it was felt that a national need existed to foster their exploration: examples are uranium and petroleum. Gold mining, for other reasons, has been free of income tax since 1924. At certain times other sections of the industry have been temporarily protected by licensing imports of cheaper overseas products.

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.

A policy of permitting partial exports of manganese ores, even when reserves were low, brought satisfactory results some years ago. At a time when manganese was in critically short supply, the export of its ores had been prohibited; however, the subsequent easing of the embargo to allow the export of one-third of any newly discovered reserves touched off an intensive prospecting campaign which brought new deposits to light.

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 of our own 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

	1967/68 Value (f.o.b. $'000)	%	1968/69 Value (f.o.b. $'000)	%	1969/70 Value (f.o.b. $'000)	%	1970/71 Value (f.o.b. $'000)	%	1971/72 Value (f.o.b. $'000)	%
Industrial Groups -										
Agriculture	636,148	21.8	583,206	18.1	657,953	16.7	872,342	20.9	965,792	20.5
Pastoral -										
Wool	715,731	31.6	795,534	24.7	761,043	19.4	543,827	13.0	583,675	12.4
Other	369,797	5.6	392,040	12.1	551,953	14.0	553,252	13.2	699,896	14.9
Dairy and farmyard	97,090	3.3	82,877	2.6	109,764	2.8	107,654	2.6	120,919	2.6
Mines and quarries (other than gold)	479,386	16.4	633,700	19.7	954,188	24.2	1,036,577	24.8	1,100,978	23.3
Fisheries	36,325	1.2	41,154	1.3	42,841	1.1	59,762	1.4	76,005	1.6
Forestry	4,785	0.2	4,740	0.1	5,811	0.1	5,920	0.1	7,303	0.2
Total Primary Produce	2,339,262	80.1	2,533,251	78.6	3,083,379	78.3	3,179,334	76.0	3,554,568	75.5
Manufactures	467,891	16.0	565,969	17.6	719,023	18.3	853,520	20.5	989,829	21.1
Refined petroleum oils	32,208	1.1	25,560	0.8	26,731	0.7	40,080	1.0	57,786	1.2
Unclassified	80,422	2.8	97,592	3.0	107,345	2.7	106,677	2.5	103,396	2.2
Total Australian Produce (excluding gold)	2,919,783	100.0	3,222,373	100.0	3,930,898	100.0	4,186,631	100.0	4,705,576	100.0

SUMMARY OF ORE RESERVES AND MINERAL PROCESSING

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

Very large - sufficient for more than 100 years ahead

Large - sufficient for 30-100 years ahead

Adequate - sufficient for 15-30 years ahead

Small - sufficient for 5-15 years ahead

Very small - less than 5 years ahead

In some cases, the uncertainty of reserves is indicated.

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

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY 1973

	Resources			Mineral Processing			
Metal or Mineral	Distribution	Reserves	Current 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 - (developing)	Very large	-	Concentrates. Metal, oxide (1973)	W.A.	Metal & alloys.	Metal available but remote from most industrial centres.
Chrome	Minor- Victoria	Very small (?)	Bulk of requirements	Ferro-chrome	Newcastle	Ferro-chrome	Largely dependent on imports.
Manganese	Groote Eylandt, N.T. W.A. (Westralia Ores etc.)	Large (metallurgical)	Battery Grade	Ferro-manganese	Tasmania only	Some ferro-manganese and metal	Main reserves N.T. No battery grade No metal capacity
Tungsten	King Island, Tasmania. Minor-N.S.W., Qld., N.T.	Adequate	-	Concentrates	-	Tungsten	No metal capacity (but could be produced).
Molybdenum	Minor-N.S.W. Tas.	Very small	All requirements of ore and concentrates	-	-	Ferro-molybdenum molybdic acid	No domestic capacity of acid and ferro-molybdenum in emergency

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

Metal or Mineral	Resources: Distribution	Resources: Reserves	Resources: Current Imports	Mineral Processing: Level of Processing	Mineral Processing: Distribution	Mineral Processing: Current Imports	Possible Disadvantages in Emergency
Non-Ferrous							
Tin	Well distributed. Major-Tasmania	Adequate	-	Metal	Sydney only	Some Tin-plate	Major deposits off mainland. Only one smelter.
Lead	Well distributed	Large	-	Concentrates, bullion and metal	Metal, N.S.W., S.A.	-	-
Zinc	Well distributed	Large	-	Concentrates, metal	Metal, Tas., N.S.W., S.A.	-	-
Copper	Mainly eastern Australia	Large	-	Concentrates, blister, metal and fabricated	Metal, Qld. & N.S.W.	-	-

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

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

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

Metal or Mineral	Resources: Distribution	Resources: Reserves	Resources: Current Imports	Mineral Processing: Level of Processing	Mineral Processing: Distribution	Mineral Processing: Current Imports	Possible Disadvantages in Emergency
Light Metals							
Aluminium	Northern and S.W. Australia	Very large	-	Alumina and metal	Metal, N.S.W., Vic., Tas.	Minor shapes	Major resources N. Aust. Alumina, Qld. & W.A. remote from refineries.
Magnesium	Well distributed (magnesite)	Adequate	35% magnesite imported	No metal produced	-	All metal	Metal can be produced as in last war.
Nuclear							
Uranium	Northern Australia, W.A. & S.A.	Large to very large	-	U_3O_8 (yellow cake) radioisotopes	Northern Australia Sydney	Radio-isotopes	Reserves widespread but current plants in Qld. & N.T.
Berylium	N.S.W. & W.A.	Small but uncertain	-	No processing	-	-	No metal capacity.
Fuels							
Coal	Eastern Australia mainly	Very large	Some high quality anthracite	Coke, coal gas	Coke-Qld., N.S.W., S.A.	Petroleum Coke	No chemical plants
Petroleum	Well distributed	Inadequate-self-sufficiency 1972 - 70%	about 35% crude supplies	Refinery products	Well distributed	Some refinery products	major supplies offshore. Import of heavy crudes

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

	Resources			Mineral Processing			
Metal or Mineral	Distribution	Reserves	Current Imports	Level of Processing	Distribution	Current Imports	Possible Disadvantages in Emergency
Chemical Fertilizers Phosphorus (Phosphate rock)	N.W. Qld.	Very large	All requirements	-	Super made in all states.	Some mixed fertilizers	Dependent on imports until N.W. Qld. deposits exploited-domestic resources only in N.W. Qld. requiring coastal transport
Potassium Fertilizers	W.A.	Appear adequate	All requirments.	-	Fertilizers all states	Some mixed fertilizers	Dependent on imports until Lake McLeod in production. Deposits remote from factories.
Sulphur	(sulphides) well distributed	Elemental nil, Sulphide adequate	55% of requirements as elemental	Acid plants	Well distributed	-	Imports needed beyond capacity of sulphide acid plants.
Salt	Well distributed	Unlimited	-	Sodium, salt, chlorine	Well distributed	Some chlorine, 50% caustic required.	-

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

	Resources			Mineral Processing			
Metal or Mineral	Distribution	Reserves	Current Imports	Level of Processing	Distribution	Current Imports	Possible Disadvantages in Emergency
Minor Metals							
Vanadium	W.A. Qld (oil shale)	Probably adequate - not developed	-	-	-	All vanadium & composites	No production
Bismuth	Well distributed - mainly N.T.	Adequate - N.T.	-	Crude bismuth bullion - Tennant Creek 1973	-	All metals	No metal capacity
Cobalt	Eastern Australia, W.A.	Small - uncertain (main potential from nickel ores)	-	Oxide (by-product)	Tasmania W.A.	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 operations, but could be produced
Cadmium	Broken Hill Mount Isa	Adequate	-	Metal (by-product)	N.S.W., S.A., Tasmania	-	-

MINERAL SUFFICIENCY IN AUSTRALIA