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MINERAL RESOURCES OF AUSTRALIA

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by

L.C. Noakes and J. Ward
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INTRODUCTION

This paper, designed for Industrial Mobilisation Courses in 1977, attempts to give a broad picture of Australia's mineral industry, and of the varied and widespread resources on which it is founded. It includes a quick glance at the history of the industry and the domestic requirement for the principal minerals and ores, some notes on the chief deposits and centres of production, reference to some of the industrial activities dependent on minerals, remarks about recent important events in mineral exploration, and an attempt to foresee what lies ahead. Two important minerals, coal and underground water, are being dealt with by other speakers to the Course and, 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 in sight. Our growth as a nation has owed much in the past to the flow of population and capital which followed the early mineral discoveries. This flow reached a peak towards the end of the last century, then slackened for almost fifty years; it began again in the last two decades in the wake of exciting discoveries from which great new sources of wealth are already evident.

This new era in mineral development in Australia with its rash of discoveries and subsequent exploitation stemmed from many related factors - new exploration tools and concepts, the introduction to Australia of foreign capital and expertise, the rise of Japanese markets, and the advent of bulk carriers, to name a few - and has resulted in recent years in the mining industry surpassing wool as a mainstay of the economy at a time when rural industries in general were depressed. Statistics available do not indicate the real contribution of the mineral industry to G.D.P. but the value of exports of industrial groups within Australia, given in Table 1, shows the rising impact of the mineral industry on overseas funds as the largest single export earner in recent years. The contribution of mines and quarries in 1975-76 given as 28.6 percent of all exports, is in fact higher, because the industrial classification used in Table 1 allocates some exports by the smelting and refining sections of the industry to 'manufactures'. For example, if the value of alumina is added to mineral exports the contribution rises to 33.3 percent.

However, the mineral industry cannot be seen in perspective without identifying problems as well as achievements. The need for additional reserves of crude oil is urgent; the use of foreign capital in both exploration and development has eroded Australian equity in the industry; restricted domestic markets for processed products, amongst other factors, continue to place restraints on mineral processing; inflation and increase in domestic costs, relative to those overseas, have eroded our competitiveness and discouraged new developments; and the prosperity of the industry, inevitably based on exports although benefiting from long-term contracts, remains heavily dependent on the Japanese economy, which currently provides markets for 48 percent by value of our mineral exports. Indeed the slowing down of the Australian mineral industry in 1975-76, as a result of lower world metal prices and of checks to the economy of both USA and Japan in particular, serves as a salutary reminder of our vital concern with world economies and of our need to diversify our mineral trade as much as possible.

Reactions from Australian and foreign stock exchanges, the inevitable failure of some ill-equipped small mining companies, and other regrettable but spectacular events following recent boom years tended to exaggerate the situation and to obscure the fact that in terms of development and production the industry has continued to progress. The phenomenal rate of annual increase in production has been lowered but not reversed. The value of ex-mine production and of exports continued to rise in 1973, 1974, 1975 and 1976 and on evidence to date will continue to rise in 1977. The level of exploration funds, certainly in real terms, declined in 1974 and 1975, and probably again in 1976; it is important that this trend be reversed if Australia is to be provided with the additional ore deposits required for continued development of the mineral industry in the 80s, and is to be able to make proper assessments of its resources.

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

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

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

At the end of these notes reference is made to some of the policies followed in recent years with the intention of encouraging development or of conserving national resources. Attached also is a summary of ore reserves and of mineral processing in Australia as an indication of both resources and processing facilities. Overseas trade in minerals and mineral sufficiency are illustrated in the diagram showing values of imports and exports of minerals in 1975, which is attached at the end of the report. The table and diagram are perhaps more effective in illustrating the present situation than any amount of text can hope to be.

The minerals discussed are grouped under the following headings -

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

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

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

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

(e) Other metals;

(f) non-metallic minerals;

(g) Fertilizer minerals;

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

Mineral statistics given are those for 1975, the latest calendar year for which complete figures are available.

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

DEVELOPMENT OF THE MINERAL INDUSTRY

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

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

Early Settlement and Exploration

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

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

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

The first metalliferous mines did not open until the 1840s. Silver-lead ores were mined in 1841 near Adelaide in territory subsequently to become South Australia, and copper at Kapunda in the same general area in 1842.

In the same decade but farther east in New South Wales the first pig iron was produced from bog iron ore deposits at Mittagong near Sydney, although the enterprise found great difficulty in competing with imported material and eventually ceased operation in the 1860s.

Establishment of the Mineral Industry

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

It was not long before new interest and expertise in prospecting led to the discovery and exploitation of other metals; the start of tin mining near Inverell, New South Wales in 1871 and at Renison Bell, Tasmania in 1872 heralded very considerable tin production in eastern Australia, which in fact became the major world source of tin for nearly a decade in the late 70s and early 80s. Copper mining was rejuvenated by discoveries at Cobar, NSW, in the early 70s, and the finding of Mount Morgan in Queensland in 1822 and of Mount Lyell in Tasmania in 1885; although the two latter deposits were first mined for gold they provided large reserves of copper ore toward the close of the century. The mineral industry was further diversified with the discovery of the rich silver, lead, and zinc lodes at Broken Hill, New South Wales, in 1883, which, to the credit of the pioneers of that field, were developed to the stage of local smelting by 1885 and as feed to larger smelters at Port Pirie by 1889.

Up to this time successful mining had been restricted to eastern and southern Australia, despite attempts to discover payable gold in the Kimberley and Pilbara divisions of Western Australia and in areas east of Perth. However, discovery of payable alluvial gold near

Coolgardie in 1893 and subsequently of the gold lodes of Kalgoorlie extended profitable mining to the western portion of the continent at a time when the economy in the east badly needed new outlets.

The Lean Years

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

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

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

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

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

<u>The Boom Years</u>

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

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

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

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

But perhaps the most notable changes brought about by the upsurge of the mineral industry concern overseas funds and the Australian economy as a whole. The value of mineral exports has risen from $69 million in 1950 to $3 157 million in 1975, to provide currently about 36 percent of Australia's overseas earnings and to recently replace the agricultural and pastorial industries as Australia's largest export earners. The mineral industry produced in 1965 what was probably the first favourable balance of overseas mineral trade this century; this favourable balance has grown from $5 million in 1965 to $2 508 million in 1975 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 saved Australia from currency devaluation and import restrictions in the late sixties. Reserves of iron ore, black coal, and bauxite, which supported about 68 percent of Australian mineral exports, are very large and, combined with long term contracts and rising demand for minerals throughout the world, promise continued major production and export.

However, upsurge of the mineral industry since the Second World War brought problems as well as achievements. The cost of exploration and development far exceeded the funds available in a country with a population not yet 14 million; overseas funds were sought and accepted in terms of risk capital for exploration and investment in mining operations, with inevitable erosion of Australian equity in both petroleum and mining industries. Moreover, since ore reserves are wasting assets, a continued flow of risk capital is required in the future to provide more reserves, particularly of crude oil if Australia's 71 percent self-sufficiency in oil in 1975 is to last.

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

Inflation in Australia is currently increasing the cost of exploration, development and production, reducing profitability, increasing cut-off grades and discouraging new developments, particularly where real world metal prices, such as those for copper and nickel, have not kept pace with inflation. Restraints to mineral development were also increased by changes in taxation schedules and particularly by the repeal of provision for accelerated depreciation in the mineral industry although changes in 1976 provided more encouragement.

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

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

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

IRON AND FERROALLOYS

Australia has for a long time been largely self-sufficient in the production of iron and steel, and exports have acted chiefly as a buffer between domestic production and demand. Some special steels and shapes and some 35% of our ferroalloys are imported.

Iron and Steel: Production of iron ore for iron and steel-making in 1975 was about 98 million tonnes, an increase of one percent above the output in 1974. Despite reduced demand and considerable industrial unrest, production of raw steel in Australia increased to 7.8 million tonnes in 1975, one percent above that in 1974; production of pig iron increased by 3 percent to 7.5 million tonnes in 1975. Although domestic demand was substantially reduced, production of structural flat, and sheet products was maintained to some extent early in the year at Whyalla and Port Kembla through export sales.

Despite reduced demand overseas, exports of crude steel more than doubled in 1975 to 1 636 000 tonnes, valued at $193 million, thereby offsetting reduced domestic demand for rolled or finished steel products. Production capacity for pig iron is surplus to domestic needs and exports were valued at $47 million in 1975. There is a substantial trade in rolled and shaped iron and steel products; exports were valued at $379 million in 1975 and imports at $173 million.

Domestic iron and steel making absorbed 11 million tonnes of iron ore in 1975. The main sources were the Middleback Ranges in SA, Mount Whaleback, Koolyanobbing, and Yampi Sound, W.A. A small charcoal-iron plant at Wundowie near Perth, which produces special grades of pig, using charcoal as a reductant, consumed 98 000 tonnes of ore from Koolyanobbing in 1975; 17 000 tonnes of iron oxide, mainly magnetite, were imported chiefly from Canada and the Philippines in 1975 for use as a heavy medium in the coal washing industry. In addition to the iron ore consumed in Australia, about 80 million tonnes of ore including 9 million tonnes of pellets were exported, slightly less than the 84 million tonnes of ore including 9 million tonnes of pellets exported in 1974. Exports were principally from Western Australia; Tasmania continued to export pellets. Although reduced demand resulted in a fall in the quantity of iron ore exported in 1975, the f.o.b. value of exports increased to $749 million ($589 million in 1974) because of increased prices.

Even in the 1940s and 1950s reserves of iron ore in Australia were regarded as too low for safety in comparison with our long-term industrial needs, and few foresaw the possibility of major new discoveries. Because of this a complete embargo on the export of iron ore had been maintained for more than twenty years. Since the embargo was eased in 1960 new discoveries have shown that we possess within our shores one of the most important iron provinces in the world, and a major export trade has been established.

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

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

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

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

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

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

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

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

Manganese is one of the key metals in the manufacture of steel, its chief use being as a de-oxidizer and a de-sulphurizer in the plant process; adequate supplies of its ores are an essential for the long range security of the steel industry. Current usage requires about 30 lb of manganese dioxide for every tonne of steel produced. It is also a hardening constituent in many grades of steel; and high-quality manganese dioxide is used in the manufacture of dry cell batteries. In 1975, 185 000 tonnes of manganese ore were required by our industries; our self-sufficiency in this mineral for most purposes has only recently been proved.

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

As with iron ore, manganese was subject to a long-standing embargo on exports, but this was partly relaxed in 1956 to allow for shipments of a portion of any new discoveries made. This was designed to encourage exploration and resulted in a burst of prospecting activity in northwestern Western Australia, during which many new small deposits were revealed, amounting in all to several million tonnes. In 1960 a discovery of much greater importance was made by the Bureau of Mineral Resources at Groote Eylandt, in the Gulf of Carpentaria, where BHP have now established an open cut mine and treatment plant. Shipments of ore from Groote Eylandt have increased to supply most of Bell Bay's ferromanganese requirements, plus an export surplus. This deposit can supply all of Australia's requirements for metallurgical grade ore for a long period to come; however, we have no supplies of battery-grade ore and continue to use imported ore at the rate of about 1 400 tonnes per year.

Australian production of manganese ore in 1975 was about 1.6 million tonnes. Exports exceed 1.2 million tonnes annually, mainly to Japan and European markets. Imports have shown a marked decline from 1965 and were about 180 tonnes of ore in 1975. Australia's production of high carbon ferromanganese now satisfies local demand, but imports of other grades including powder totalled 4400 tonnes in 1975. Since the cessation of production in the Port Hedland district of Western Australia in 1973, Groote Eylandt is now the only large scale producer of manganese ore.

Molybdenum: Before 1920 substantial quantities of molybdenite were produced in Australia, but for many years production has been small. No domestic production of Commercial-grade molybdenite concentrates was recorded in 1975. Imports of molybdenum ore and concentrates fell by 70 percent in 1975 to 213 tonnes, imports of ferromolybdenum dropped by 76 percent to 149 tonnes, and imports of molybdenum oxide and hydroxide decreased from 31 tonnes in 1974 to less than 1 tonne in 1975.

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

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

Chromium: Chromite, the ore which yields the metal chromium, has two uses in the steel industry: as an ingredient in the production of alloy steel, and as a chemically inert furnace lining. Its other main use is in the manufacture of chemicals. Australian annual consumption of chromite runs at about 12 000 tonnes, all of which is normally imported. In 1975, 9600 tonnes of chromite were imported, mainly from the Philippines. Imports of ferrochrome, mainly from South Africa, decreased to 5000 tonnes in 1975.

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

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

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

The principal deposits are in Tasmania and Queensland. Wolfram comes mainly from Avoca, Tasmania, where Aberfoyle and Storey's Creek mines have been the principal producers; and from Mount Carbine in northern Queensland where R.B. Mining Pty Ltd are operating. A major deposit of scheelite exists on King Island, Bass Strait, but fluctuating world prices have made operations irregular and for a time the mine depended upon the receipt of a Government subsidy. A fresh contract has revived operations in recent years, and known reserves have increased sharply from 1.47 to 7 million tonnes, averaging 0.8% tungstic oxide. Efforts by producer countries, supported by Australia, to achieve an international arrangement leading to price stability have not met with success; world prices remained reasonably firm during 1969, improved in 1970, but generally declined in 1971 and 1972. In mid 1974 prices improved and by October had reached £50.00/mtu but started to fall almost immediately and by December 1975 quotations were in the region of £42/mtu. By the end of 1976, the quotations were close to £90/mtu. On 1 December 1976, quotations in the United Kingdom were changed from sterling to United States dollars.

Australian production in 1975 (expressed as concentrates of 65% WO_3 content) was 2905 tons, and recent enhanced prospects on King Island promise higher production of scheelite in the future even if operations are stopped at the high cost mines in the Avoca area. The scheelite produced at King Island contains sufficient MoS_2 to attract a penalty. A plant to produce artificial scheelite is being constructed there, and the resulting by-product MoS_2 will be sold as molybdenite. The total domestic consumption would seldom exceed 100 tons per annum, its main use being in the manufacture of tungsten-carbide tipped tools.

<u>Nickel</u>: Australia's identified resources in the past have been small and there was no significant domestic production before 1967. All our requirements were imported; the level had been rising because of the increased demand for special steels and the greater use of nickel anodes for electroplating. Consumption of nickel is estimated to have increased from about 900 tonnes in 1950 to 4 800 tonnes in 1974, but decreased to about 2000 tonnes in 1975 as a result of the economic recession.

The tightening position of world supplies in the 1960s led to intensive exploration in Australia, and many important deposits have come to light. At Kambalda, in Western Australia, Western Mining Corporation has now proved reserves estimated at 24 334 000 tonnes of sulphide ore averaging 3.20% nickel and at Ora Banda the company has identified in excess of 30 million tonnes of lateritic resources considered to be subeconomic at present.

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

Drilling by Great Boulder Mines Ltd and North Kalgurli Mines (1912) Ltd at Scotia near Kalgoorlie revealed about 1.2 million tonnes of nickel sulphide ore plus 2.0 million tonnes of 1.41 percent nickel at neighbouring Carr Boyd Rocks. Mining at Scotia commenced in 1970 and is still in progress whereas mining commenced at Carr Boyd Rocks in 1973 and was suspended in June 1975 because of unfavourable economics. The Windarra Nickel Mines project (WMC/Poseidon) at Mt Windarra and South Windarra had ore reserves of 9.1 million tonnes averaging 1.49 percent nickel at 30 June 1976. Production from Mt Windarra commenced in the last quarter of 1974. Smaller ore shoots have been discovered in the Widgiemooltha area by

Anaconda-CRA, the Selection Trust Group and BHP-International Nickel. Anaconda-CRA started production from their Redross orebody in 1973 and the Selection Trust Group from their Location 3 orebody in early 1975. Metals Exploration-Freeport International have developed a lateritic orebody at Greenvale in Queensland and have constructed a refinery to produce nickel oxide at Yabulu near Townsville. Production at the refinery commenced in December 1974 and when full scale production is reached in 1977 output from the refinery will be 25 000 tonnes/year of nickel in oxide and mixed sulphide product. The Selection Trust Group have discovered and proved a very large nickel sulphide deposit at Agnew 350 km north of Kalgoorlie and have formed a joint venture partnership with MIM Holdings with a view to bringing the project into production in 1978.

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

Production of nickel concentrates commenced in June 1967 at Kambalda and output for that year was 2060 tonnes of contained nickel. In 1975 mine production of nickel was 75 825 tonnes and this figure will be exceeded in 1976 as recently developed projects move towards full scale production. Australia is now the third largest producer of nickel in the non-Communist world. In 1975 about 80 percent of the nickel mined was domestically processed to either metallic nickel, high grade nickel matte or sintered nickel oxide and this figure will increase in 1976. The nickel refinery at Kwinana near Fremantle commenced production in 1970 with an output of 15 000 tonnes/year of metallic nickel. Output in 1975 was about 26 000 tonnes/year and WMC has announced plans to increase this figure to 30 000 tonnes/year. WMC commissioned a nickel smelter at Hampton near Kalgoorlie in 1972 with a capacity of about 18 000 tonnes/year of nickel in matte, but this has since been increased to about 40 000 tonnes/year and plans were announced in 1976 to double the capacity in the next few years.

BASE METALS

Copper: The first production of copper was recorded in the Kapunda field of South Australia in 1842 and at Burra in 1846. In the early years, Australia was one of the worlds' leading producers, but during the first half of this century her known deposits were slowly depleted, no new ones were found, and it appeared that she would soon become largely dependent upon imports. However, this possibility was dispelled by the confirmation of very large reserves of copper ore, first discovered in 1931, adjacent to the lead-zinc lodes at Mount Isa. Since then other deposits have been found in several parts of the continent, and working mines like Mt Lyell have been shown to have greatly increased reserves. Important discoveries of copper mineralization have been made recently in acid volcanic rocks of Western Australia. Exploration is continuing at these and other prospects and for some time Australia can be expected to provide not only for its own needs, but for a significant export trade as well.

The Australian scene is dominated by Mount Isa, which produced 63% of the total in 1975 and has reserves sufficient to support a high rate of production for over 25 years. Other important centres are Gunpowder, Qld; Mount Lyell, Tas; Cobar, NSW; and Mount Gunson, S.A.

It is interesting to observe that the full potential of the Mount Isa deposits was not realized until the early 1950s, although copper was mined for emergency purposes from some minor lodes during the war years. After the discovery by drilling of high-grade copper lodes, a major new enterprise got under way in 1953 and output has since grown steadily. The Mount Isa-Cloncurry region of Queensland is the most important copper mining province in Australia both historically and on the basis of mine production. About 1.5 million tonnes of copper have been produced since 1884. Most of the copper has been recovered from the Mount Isa mine.

Domestic mine production has been increasing steadily in recent years because of expanded output from the Mount Isa and Mount Lyell mines and the commissioning of several new mines in the late 1960s and early 1970s. Record levels of production were achieved in each of the three consecutive years after 1968, and again in 1973 and 1974.

Details of copper in all mine products from the States in 1975 are as follows:

		Tonnes (metal)
Queensland		
Mt Isa	138 877	
Mt Morgan	8 726	
Mammoth Mine	8 830	
Others	200	156 633
New South Wales		
Cobar	9 938	
Broken Hill	3 424	
Others	54	13 416

Tasmania		
Mt Lyell	22 955	
Others	3 505	26 460
Western Australia		4 610
South Australia		
Burra	1 898	
Kanmantoo	6 770	
Mt Gunson	9 150	17 818
Northern Territory		
Tennant Creek Mines	2 593	
Others	1	2 594
Total		221 531

Australia has two copper refineries - at Port Kembla and at Townsville. A third at Mt Lyell was closed down several years ago. The refinery at Townsville, a wholly owned subsidiary of Mount Isa Mines, with an annual capacity recently expanded to 155 000 tonnes, is by far the larger. It was commissioned in 1959 and refines the whole of the Mount Isa output. In 1975, 86% of the copper in copper concentrates produced in Australia was domestically processed to blister or refined metal. It is expected that the level of domestic processing will rise during the next decade as output from the Cobar field (refined at Port Kembla) increases and the Tennant Creek smelter is recommissioned.

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

Since the discovery, in 1883, and the development of the Broken Hill silver-lead-zinc orebody, perhaps the richest in the world, Australia has been a major producer of lead and zinc ores; and her already dominant position was reinforced by the discovery and exploitation of Mount Isa in the years following 1923. It is interesting to note that Australian metal mining began with silver-lead in South Australia in 1841. We have been amongst the world's leading producers of lead for a number of years past and in 1975 with a production of 407 778 tonnes we ranked as the third largest producer in the world behind USA and USSR. Our known resources are sufficient to allow us to continue as a major exporting country for several decades to come.

Mine production of lead has run uniformly high in recent years, after being below capacity in 1970-71, when it was affected by an international arrangement under which a substantial part of Australian production was voluntarily curtailed. Output in 1975 was below capacity, but considerably higher than in 1974 when production was curtailed by industrial stoppages at Broken Hill and flooding at Mount Isa.

Details of lead in all mine products from the States in 1975 are as follows:

		Tonnes
New South Wales		
All Broken Hill mines	242 370	
Others	2 268	244 638
Queensland		
Mt Isa		142 633
Tasmania		
Read-Rosebery		19 552
Other States		955
Total		407 778

Most of our lead concentrates are smelted in Australia. There are smelters at Mount Isa, Queensland, and Cockle Creek, NSW, which produced 153 290 tonnes of lead bullion in 1975, and a smelter and refinery at Port Pirie, SA, which produced 168 425 tonnes of refined lead. Domestic consumption was 68 998 tonnes (including 30 000 tonnes from scrap). Most lead concentrates produced domestically are refined in Australia to bullion or to refined lead.

Zinc: For a number of years Australia has ranked fourth behind Canada, USA, and USSR as the world's leading producers of zinc ores. In 1969, mine production reached a record 510 000 tonnes and refined zinc output reached 246 000 tonnes. Output in subsequent years was reduced by voluntary cutbacks (1971), industrial problems and lower ore grades. Mine production was 500 846 tonnes in 1975, from which 193 310 tonnes of zinc were refined. Mine production was slightly higher than in 1974; most major producers elected to maintain production and build up stocks rather than reduce output. Refined zinc output fell by 30 percent because of production cutbacks by all major producers in early 1975.

Details of 1975 production are as follows:

		Tonnes
New South Wales		
Broken Hill Mines	280 490	
Others	8 341	288 831
Tasmania		
Read-Rosebery		67 476
Queensland		
Mt Isa		130 234
Total		500 846

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

About 62% of our total zinc concentrates (all from Tasmania, and some from Broken Hill) were treated at these plants in 1975. The remainder of concentrates from Broken Hill and all those from Mount Isa were exported. In 1975, production of refined zinc was 200 310 tonnes (including 7000 tonnes from secondary sources). Domestic consumption fell by 32 percent to 81 881 tonnes of refined zinc, of which 74 880 tonnes was of primary origin.

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

In 1969, production of tin in concentrates rose to 8308 tonnes, the highest since 1913, and it increased further to 11 997 tonnes by 1972. However, mine production fell in 1973. Production of refined tin also reached a peak in 1972, of 7027 tonnes, and fell to 6714 tonnes in 1974. The International Tin Council imposed export quotas in April 1975, which remained in force until June 1976. These quotas, together with abnormally low domestic consumption, resulted in a substantial fall in both mine and smelter production in 1975, to 9 577 tonnes of tin in concentrates and 5 254 tonnes of primary refined tin.

With the removal of the export quotas, mines have returned to full production; as several were expanding production capacity before quotas were imposed, mine production in 1976 should be slightly more than in 1975, and should increase substantially in 1977. Smelter production is likely to be less than in 1975, and not to increase greatly in 1976.

Imports in 1975 were 28 tonnes of refined tin; exports were 2470 tonnes of refined tin, and 11 166 tonnes of concentrates containing 4521 tonnes of tin. Estimated consumption of primary refined tin in the same year was 3258 tonnes, the lowest annual consumption since 1958, and 24 percent less than in 1974. Consumption in 1976 will probably be well below the 1974 total again.

Tinplate accounts for more than half the domestic consumption of tin. Production of hot-dipped tinplate commenced at Port Kembla in 1957; an electrolytic line was commissioned in 1962 and another in 1973, and the hot-dipped line closed in 1972. Technological advances have resulted in a progressive decrease in the amount of tin consumed per unit area of tinplate produced. Tinplate is susceptible to substitution by other packaging materials, but increases in energy costs or costs of raw materials have affected adversley the competitivness of substitutes such as aluminium and plastics.

Associated Tin Smelters, operating at Alexandria, NSW, is the only domestic producer of primary refined tin. Annual smelter capacity is rated at 15 000 tonnes of concentrates. The predominant mine producer, Renison Limited, has announced that it is studying the feasibility of constructing its own smelter.

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

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

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

URANIUM, THORIUM ETC.

Uranium: Australia is not a consumer of uranium, although small quantities of uranium-derived fuels are imported for use in research at the atomic reactor at Lucas Heights near Sydney. A few years ago we passed through a brief but spectacular interlude as a producer of uranium ore and we may now be on the threshold of becoming a more important producer. The national search for deposits began in 1944 and bore its first fruit in the discovery of Rum Jungle in 1949 and of Mary Kathleen in 1954. Some small deposits were known in South Australia as early as 1906, and others, which were to become useful but minor contributors to the output, were found in the South Alligator River area, NT, in the early 1950s. Treatment plants for the production of uranium oxide were erected at Port Pirie, where for several years rather high-cost material was produced from ores mined at Radium Hill; Rum Jungle, where the plant remained in operation treating stockpiled ores until 1971; Moline, NT, which after fulfilling the last part of an overseas contract for uranium was modified to treat Ag-Pb-Zn ores from Mount Evelyn pending resumption of uranium mining; and Mary Kathleen which commenced operations in 1956 and was placed on care and maintenance in 1963.

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

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

On the other hand the deposits at Rum Jungle were mined out and the plant continued to operate on stockpiled ore, and stockpiled the uranium oxide product, in a program that was completed in 1971. 1625 short tonnes of oxide were produced during the life of the Rum Jungle plant and the total revenue over the period of operation was $42 million. Mary Kathleen produced oxides worth $90 million up until 1964.

Meanwhile, the easing of the total export embargo announced by the Commonwealth Government in 1967 stimulated prospecting for new reserves with notable success. New deposits were found in the Westmoreland area, NW Queensland, near Lake Frome and at other localities in South Australia, at Yeelirrie in Western Australia, and, of prime importance, the substantial deposits at Ranger 1, Nabarlek, Koongarra, and Jabiluka about 230 km east of Darwin, in a major new uranium province in the Northern Territory. Reserves of uranium ore, mineable at prices up to $US15 per lb U_3O_8, were assessed at June 1976 by the AAEC to be 227 000 tonnes U, which is about 21% of the world known reserves of that grade.

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

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

Australia is well endowed with uranium reserves which account for about 21% of the total in the western world. The bulk of known reserves of uranium in the western world are in USA, Australia, Canada, and South Africa.

Thorium and Cerium: The main commercial source of thorium, which has been of interest because of its possible nuclear uses, is the mineral monazite, a by-product of beach sand operations on both the east and west coasts of Australia. Notwithstanding the use of thorium in several United States experimental reactors, large-scale nuclear uses in fast breeder reactors are said to be many years off. Although research on the nuclear application of thorium continues, commercial application of the thorium-uranium fuel cycle in the high-temperature, gas-cooled reactor (HTGR) as an industrial source of high temperature heat seems further away than ever.

An increasing interest in monazite results from its rare-earth content, particularly of cerium and yttrium. World demand for rare earths increased sharply in 1973 particularly for high strength, low alloy steels used in oil and gas pipelines. In recent years, the pattern of rare earth applications has changed from one based on the use of rare earths as catalysts to one more strongly oriented to metallurgical applications. Estimated percentage end - use applications in 1975 (compared with 1969) are: catalysts 36% (63.0%), metallurgy 45% (6.4%), glass and ceramics 17% (30.0%), TV electronics, nuclear and miscellaneous 2% (0.6%). Cerium is also present in the mineral allanite, large quantities of which are found in the Mary Kathleen uranium deposit.

High-grade monazite concentrates are recovered from beach sands in Western Australia, Queensland, and New South Wales. The monazite recovered in Western Australia is a by-product of ilmenite production, but elsewhere of rutile and zircon production. Development of extensive mineral sands deposits commenced at Eneabba about 270 km north of Perth in 1973, and the area will no doubt prove to be a major world source of monazite. In 1975 Australian production was 4507 tonnes of concentrates containing about 4160 tonnes of monazite, 78% of which came from Western Australia; Australian production amounts to about 40 percent of total world supplies of monazite. All sales were overseas before 1969, but a former uranium plant, purchased from the South Australian Government at Port Pirie, was commissioned in May 1969 to process domestic monazite. In early 1972 an annual throughput of 1300 tonnes of monazite concentrate was achieved at the plant for the production of cerium and lanthanum hydrates, yttrium oxide, thorium sulphate, and tri-sodium phosphate. However, financial and market difficulties forced closure of the plant in mid 1972.

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

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

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

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

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

Lithium ores have been produced spasmodically since 1905. In 1974 amounts totalling 1.0 tonnes were produced in Western Australia, but no production was recorded in 1975.

Several years ago a mining company undertook drilling tests on lithium prospects near Kalgoorlie and Ravensthorpe, WA, and extensive reserves are said to have been proved. These deposits would seem to ensure

Australia's supplies in any future emergency, but marketing difficulties militate against present large-scale production.

OTHER METALS

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

A series of spectacular discoveries was to change this picture completely. They began in 1949 when relatively small deposits of bauxite were found at Marchinbar Island off the coast of Arnhem Land by the Bureau of Mineral Resources; this was followed by a more substantial discovery on the mainland near Gove. Later, in 1956, very large deposits of bauxite were found at Weipa on Cape York Peninsula by an exploration company; and in 1958 important new sources were recognized at Jarrahdale, in the Darling Ranges close to Perth, where lateritic bauxites had been regarded as too low grade for commercial exploitation. In 1965, an announcement was made of the discovery of further large deposits inland from Admiralty Gulf in the Kimberley district of Western Australia, and in 1973 it was announced that extensive, lower grade deposits lay to the north of these, on Cape Bougainville. In late 1970 exploration for possible bauxite deposits beneath the Gulf of Carpentaria, offshore from Weipa, was carried out but was unsuccessful, but exploration on land south of the Weipa deposits has indicated seven hundred million tonnes of bauxite, although the grade has not been announced. Production of ore from Weipa, Jarrahdale, and Cove has mounted rapidly and in 1975 reached 21 million tonnes. Australian reserves are now known to be very large, at least 6500 million tonnes, and almost certainly the largest of any country in the world.

On the industrial side, developments have also been rapid, and imports of alumina have been relatively low (2555 tonnes in 1975) and used principally for purposes other than aluminium production since the commissioning of the Gladstone alumina refinery in 1967. The Bell Bay smelter, owned by Comalco Ltd, has been expanded to a capacity of 95 500 tonnes/year of metal and will be further expanded to 114 500 tonnes annually by late 1977. It is being supplied from Gladstone with alumina derived from Weipa bauxite. Bauxite mining and shipping facilities at Weipa are currently capable of handling over 11 million tonnes/year. An alumina plant at Kwinana, near Fremantle, WA, with a present capacity of some 1.4 million tonnes/year, is supplying feed to the smelter of Alcoa of Australia Ltd at Geelong. Alcoa commissioned a second refinery at Pinjarra, WA, in 1972, with an initial capacity of 250 000 tonnes of alumina per year, which has been expanded in stages to its present capacity of about 2 million tonnes/year. The Geelong smelter came into production in 1963 with an initial capacity of 20 000 tonnes of metal and was expanded in stages to reach 91 500 tonnes by late 1969. Alumina is also being shipped from Kwinana to Japan, the United States and Bahrain.

The CRA - Kaiser group, in partnership with several other major overseas companies, commissioned an alumina plant at Gladstone, Qld, with an output in 1967 of some 600 000 tonnes/year of alumina; this has since been expanded in stages to 2 400 000 tonnes/year. Part of this production is used as feed for a smelter at Bluff, New Zealand, completed in 1971 by Comalco in partnership with Showa Denko K.K. and Sumitomo Chemical Company. The

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

Early in 1969 an agreement was completed between the Australian Government and Swiss Aluminium and Australian partners for a project at Gove, NT, to produce 1 million tonnes of alumina and up to 2 million tonnes of bauxite for export; initial shipments of bauxite began in June 1971 and the alumina refinery came on stream in June 1972 and reached its rated capacity of 1 million tonnes/year by mid 1973. The current position in Australia therefore is: resources of bauxite of at least 6500 million tonnes and plant capacity for the production of 6.8 million tonnes of alumina and of 232 000 tonnes of aluminium, with further expansions in train or planned. Conditions of over-supply, evident in world markets in late 1971, were countered by cut-backs in the production of both alumina and metal in Australia in 1972; however, markets gradually improved in 1973 and early 1974 and production was again approaching capacity until a situation of oversupply developed on world markets later in that year. In 1976, companies progressively brought back into production capacity rendered idle during the period of cutbacks, and by the end of the year output was running at installed capacity.

<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, as a flame retardant (as the oxide), and in the plastics industry.

Domestic production of antimony in antimony concentrates in 1975 was 1542 tonnes, nearly all of which was exported. In addition 456 tonnes of antimony from Broken Hill concentrates was recovered in antomony alloys produced at Port Pirie. An additional 381 tonnes of antimony was contained in retreated railings from the old Costerfield mine dumps. In 1975, the Port Pirie refinery produced 10 382 tonnes of antimonial lead and 7988 tonnes of lead sheathing alloy containing 900 tonnes of antimony of which 444 tonnes was recovered from scrap.

Exports of antimonial lead alloy in 1975, mainly to Malaysia, amounted to 4783 tonnes valued at $1 893 000. No antimony metal was produced in Australia in 1975 and only 11 tonnes were imported; Mainland China was the sole supplier.

Antimony ores have been produced in Australia since the middle of the last century, but most deposits have been worked out. Recently, the only significant production has come from mines in the Hillgrove area in northeastern NSW - in 1975 production was 893 tonnes of antimony in concentrates.

Exploration for antimony greatly increased under the influence of world shortage and record prices in 1969-70, but with the rapid decline in price in 1971 development has been concentrated on higher grade deposits. The Blue Spec antimony-gold mine, 150 km southeast of Port Hedland, WA began production in mid-1976. The mine is expected to produce about 1500 tonnes/year of antimony and 1200 kg/year of gold over a planned mine life of 28 months. Australia is already self-sufficient in antimonial lead, but requires minor imports of high purity antimony each year.

<u>Titanium</u>: Australia's resources of titanium minerals (rutile and ilmenite) are considerable. Domestic recoverable reserves are put at about 9 million tonnes of rutile and 46 million tonnes of ilmenite, although a substantial proportion of east-coast reserves of rutile are currently unavailable for mining because of environmental considerations.

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

The traditional uses of rutile have been in the manufacture of welding rods and the production of titanium metal; since the early 1960s, by virtue of the chloride method of processing, rutile has been used in the manufacture of pigment for high-gloss white paint, an outlet which now accounts for about 60 percent of total rutile consumption. The use of ilmenite is virtually confined to pigment manufacture. However, the commercial application of processes by which ilmenite is up-graded to approach rutile in TiO_2 content (beneficiated ilmenite or synthetic rutile) provides a feed for either pigment or metal via the chloride process; beneficiated ilmenite is now beginning to complement supplies of natural rutile and in 1975 beneficiated ilmenite supplied about 20 percent of world requirements of high titania feed.

The principal Australian production of rutile is from sands on and adjacent to the beaches of the eastern coast. The discovery in 1971 of old shoreline deposits of rutile, zircon, and ilmenite near Eneabba, 270 km north of Perth, constitutes a major additional sup ly of rutile. Commerical production of rutile from this source commenced in 1975 and installed capacity for rutile production in the area is now about 150 000 tonnes/year. In 1975, production from this source accounted for about 12 percent of total domestic output of rutile concentrates. On the eastern coast much of the ilmenite which accompanies the rutile and zircon has too high a chromium content to be saleable for pigment and for the most part has been discarded or stockpiled; however, ilmenite from the more northerly deposits tends to have a more acceptable chromium content and could well provide a suitable base for the production of synthetic rutile in that area in the future.

The principal ilmenite industry has been built up along the southwestern coast of Western Australia. The quality of the ilmenite from this source is most satisfactory for the manufacture of titanium white, and as ilmenite is the main heavy mineral constituent of the sands, its recovery forms the basis of the industry. By-products of ilmenite mining are monazite, zircon, and rutile. In mid 1971 Western Titanium Ltd commissioned a commercial beneficiation plant at Capel, WA, and an annual production rate of 40 000 tonnes of beneficiated ilmenite has been achieved. Both rutile and anatase pigments are produced in Australia at Burnie, Tasmania and at Bunbury, WA. Both plants are based on the sulphate process and use ilmenite concentrates produced from the Capel deposits of Western Australia. Domestic production capacity for TiO_2 pigments is 60 - 70 000 tonnes/year. Ilmenite concentrates are exported from Bunbury, where substantial bulk loading facilities have been brought into operation. Exports of ilmenite, rutile, and zircon from Eneabba have begun through Geraldton and are expected to increase substantially in the late 1970s.

Zirconium: Australian resources of this metal, in the beach sand mineral zircon, are considerable and are almost twice those of rutile. Again, however, more than 20 percent of east-coast reserves are unavailable to mining because of environmental considerations. Zircon is produced as a co-product of rutile mining along the east coast and in the Eneabba-Jurien Bay area, WA, and as a by-product of ilmenite mining in the southwest corner of Western Australia. The market for zircon, principally required for foundries in the form of moulds, facings and cores, and for refractories and ceramics, faced oversupply in 1970 but became firm in 1973; as temporary assistance to the industry, the Commonwealth Government early in 1971 supported a stockpiling scheme initiated by industry by controlling the minimum price of zircon in export contracts. The position of oversupply quickly changed to one of short supply, and in 1973 Australia exported a record 431 000 tonnes of zircon concentrates. However, a position of potential oversupply again developed in 1975 and Government re-introduced a minimum price for zircon exports albeit almost five times as high as that in 1971. In view of the continuing adverse market situation, the floor price for zircon exports has been reduced to the range \$115-\$125/tonne, f.o.b.

depending on grade.

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

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

In 1975, mine production of cobalt totalled 2709 tonnes, of which 114 tonnes were contained in zinc concentrates from Broken Hill, NSW, 1033 tonnes in nickel concentrates produced in Western Australia and 1562 tonnes in lateritic nickel ore mined at Greenvale in Queensland; however, only a small proportion is recovered in Australia. The zinc refinery at Risdon, Tasmania, which continues to be the major supplier of cobalt for Australian industry, produced 20 tonnes of cobalt oxide (14 tonnes of cobalt) from zinc concentrates in 1975. A nickel-cobalt sulphide product is produced at the nickel refinery at Kwinana and the Yobulu refinery near Townsville, but these products will be exported rather than further refined in Australia in the immediate future. These by-products would make Australia self-sufficient in cobalt if suitably refined; in the meantime a large part of our requirements are imported in the form of metal and compounds, mainly from Zaire (the world's principal producer), Canada, Morocco, and Zambia. The USA is an alternative source from which imports are also obtained.

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

Production of refined cadmium in 1975 was 549 tonnes of metal; 365 tonnes came from Risdon, 152 tonnes from Cockle Creek, and 32 tonnes from Port Pirie. Mount Isa produce a cadmium-thallium sponge which is exported, and reported production of 20.6 tonnes of this material in 1975. Domestic sales in 1975 were about 133 tonnes and the rest was exported, including cadmium contained in lead-zinc concentrates. Australia is more than self-sufficient in this metal, but the United States, Canada, and Japan are alternative sources.

Magnesium and Calcium: These are derived from the similar sources dolomite and limestone, of which Australia has an abundance. Elsewhere in the world, magnesium is produced from seawater; however, there is no production of magnesium in Australia. Magnesium is well known as a light-weight metal, being only 2/3 of the weight of aluminium. Suitably alloyed to increase its strength, it has been used increasingly in the aircraft and allied industries. Calcium is a soft metal, of little use on its own, but effective as a hardener of lead. Neither metal is produced in Australia, although magnesium was smelted in limited amounts at Newcastle during the war. Australian resources for production are more than ample.

Gold: Annual production, once steady at above 1 million ounces (32 150 kg) has been falling slowly for a number of years. In 1970, reflecting the difficulties confronting the gold mining industry, production fell to 17 600 kg. However, rising gold prices in 1971 and 1972 reversed the trend and production rose to 19 000 kg in 1971 and to 23 500 kg in 1972, but production then declined to 15 984 kg in 1974, and increased slightly in 1975 to 16 247 kg. In 1975, 41 percent of domestic gold production came from gold mines in Western Australia, with a very small contribution from gold mines in Victoria. The remainder (59% of production) came from the Northern Territory where, because of low copper prices, Peko-Wallsend Ltd concentrated on the gold-rich portions of the ore bodies in the area and stopped production of copper. The major disability suffered by the gold mining industry in recent years was that whereas the price of gold had been fixed for more than 30 years, the cost of production had mounted steadily. In order to keep marginal mines in operation and to maintain existing communities in a number of isolated places, the Commonwealth Government introduced various forms of assistance, including a subsidy on production which was last increased in January 1972. However, subsidy payments cut out when the price exceeded $54 per oz. Gold's main use was that of a dollar earner, with a world price of US$42 per troy oz. However, in 1968 the International Monetary Fund agreed to a two-tier system under which gold might be traded at higher than the official price; in general, this system together with other measures induced a rising free market price for gold, promising some rejuvenation of gold mining in Australia, but this promise was not fulfilled and production in 1973 fell. The two-tier system was abandoned in November 1973. Production is expected to decrease slowly in the future. The price of gold was US$195/fine ounce at the end of 1974 but by December 1975 the price had fallen to about $110. In 1976 the downward movement in the price of gold continued until the end of August when it had fallen to $83/fine ounce. By 26 November 1976 the price had recovered to $106. Following devaluation of the Australian dollar on that date the price on the 27 November was $128. Since then the price has moved downwards slightly mainly on account of the re-valuation of the Australian dollar, and on 25 January it was $122/fine ounce.

In August 1976 the Government announced that it had accepted the main recommendation of an IAC report on the gold mining industry published in June 1975. The report advocated the phasing out over 5 years of taxation exemptions to the industry. After representations from interested parties the Government announced in mid-August 1976 that the whole question of assistance, including taxation exemption, to the gold mining industry was being referred back to the IAC for further consideration. The Commission is expected to report to the Government in March 1977. The existing provisions of taxation will apply at least until the report is received by the Government.

Tantalum-Columbium: Tantalum and columbium (niobium) are metals used in alloying, in high-temperature corrosion-resistant chemical ware, for tipped tool cutting purposes, and in anodes and grids for electronic equipment. Australia was formerly a prominent producer of the ores of these metals (tantalite and columbite), but production has fallen to very low levels. In Western Australia there is commonly a small annual output, mainly as a by-product of tin mining. This amounted to about 130 tonnes of combined concentrates in 1975; and was all exported. There is no domestic demand but if one arose in time of emergency, some of the known deposits could most probably be reopened to satisfy the requirement.

Platinum Group Metals: The main uses are in chemical ware, in jewellery, in alloys for electrical purposes, and in the petroleum and glass industries. There has been a small erratic production of platinum and osmiridium for over 70 years, but known resources have never amounted to much. Small deposits have been worked in Tasmania and New South Wales, but very little production has been recorded from them since 1968. A small amount is commonly recovered annually as a by-product of gold refining at Port Kembla. Platinum is now recovered from nickel co-products produced at the Kwinana nickel refinery. In 1975 production from this source was 309 kg of platinum group metals.

Imports in 1975 were valued at $2.05 million and exports of 550kg were valued at 1.3 million. Canada and South Africa are among the world's leading producers and overseas demand is strong. Both producer and free market prices, stable in 1969, have since declined as a result of current world oversupply. Any future increase in demand for platinum will depend on the U.S. Environmental Protection Authority's decision concerning the use of platinum in catalysts in converters for the control of pollution from automotive exhaust gases. The EPA has postponed its decision concerning the use of such converters until after 1982.

<u>Selenium and Tellurium</u>: Selenium is used in small quantities in the electronic, chemical, glass, and metallurgical industries, but is being replaced in some of its uses with the cheaper materials silicon and germanium. There is some production from tankhouse slimes in the electrolytic copper refinery at Port Kembla, but no statistics are available. Peko Wallsend Ltd produces concentrates containing gold, bismuth copper, silver and selenium at the Juno and Warrego mines, Tennant Creek; output for 1975 was 5266 tonnes of concentrate containing 33 906 kg of selenium compared with 2671 tonnes of concentrate containing 29 000 kg of selenium in the previous year. Domestic consumption is not large. Leading overseas producers are USA, Canada and Japan.

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

<u>Bismuth</u>: There has commonly been a small annual production of concentrates of bismuth as a by-product of tin and tungsten concentrates from the Northern Territory and Western Australia. In 1967, the Juno gold mine at Tennant Creek recorded the first domestic production since 1962. Production since then has expanded considerably with the production of bismuth concentrates from gold ores at the Peko and Warrego mines. In 1975, domestic output was 817 400 kg, 30 percent below the record production of the previous year. The bismuth occurs with copper and gold and much of the bismuth reports in copper-bismuth flue dust, a by-product of copper smelting. Research is continuing into methods of processing bismuth concentrates to bismuth bullion containing about 90 percent bismuth metal. Imports of bismuth metal declined to 4948 kg in 1975, having ranged between 12 000 and 22 000 kilograms

in the period 1970-74. Present uses of bismuth are for alloys with precise melting points and for the production of salts used in the pharmaceutical and chemical industries. The use of bismuth as a metallurgical additive to aid the casting of iron and improve the machinability of aluminium and steel has increased in recent years. The continued strength of this market will depend on production in the ferrous and aluminium industries.

Mercury: Australian reserves are negligible. Mercury was produced early in 1967 for the first time since 1945. In 1975, 341 kg were recovered as a by-product from the treatment of Rosebery lead-zinc ores at Risdon. Imports of mercury in 1975 were 55 616 kilograms mainly from Spain, China, and USSR. World production during 1975 was some 8.7 million kg. World consumption of mercury continued to decline in 1975 because of pollution fears.

Silver: Most of the silver mined in Australia is mined as a by-product of lead mining, but some silver is also produced as a by-product of zinc, copper, and gold mining. Mine production in 1975 was 726 218 kg most of which came from the lead-zinc industry. Silver refined in Australia in 1975 was 279 050 kg and almost all the rest of the silver mine production was exported in base-metal concentrates, or lead bullion.

Vanadium: This metal, used in both ferrous and non-ferrous alloys, and in the chemical industry, is a common constituent of minerals, though there are relatively few deposits mined. None has been produced in Australia and local consumption is negligible, but recent exploration has indicated possible economic hard-rock deposits in Western Australia, and potential supplies as a by-product of petroleum recovery from oil shales in northwestern Queensland. Sources of supply, if required, would be the United States, South Africa, Finland, and Southwest Africa. World production in 1975 was about 21 000 tonnes.

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

NON-METALS

<u>Abrasives</u>: Australia is deficient in resources of natural hard abrasives, such as diamond, used in many industrial cutting processes, and in corundum and emery. Production of all these is negligible. Small amounts of industrial diamonds were once obtained as a by-product of gold dredging in the Macquarie River, New South Wales, but today the total domestic requirement is imported; imports totalled 923 761 million metric carats in 1974-75, but a considerable amount (214 205 m. carats) was re-exported. The republic of Zaire is the world's major producer, followed by the USSR and other African countries. Some interest has been expressed from time to time in the possibility of diamond deposits in Australia; at present at least one company is active in Western Australia - but so far without a discovery of economic importance. Corundum and emery have been mined on a small scale in Western Australia but there is now no domestic production, and imports commonly amount to about 1300 tonnes, mainly for use in optical polishing. Rhodesia is the world's leading producer of corundum followed by the USSR and South Africa. Turkey is easily the largest producer of emery.

Part of our requirement of garnet is normally obtained as a by-product of mining mineral sands along the eastern coast: no production was recorded from this source in 1975. The bulk of domestic requirements is met by imports, mainly from the United States.

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

Arsenic: In 1975, Copper Refineries Pty Ltd at Townsville commenced production of copper arsenite at the rate of about 200 tonnes/year. This is the first recorded production of arsenic on a commercial scale since 1952. Apart from the production at Townsville all domestic requirements of arsenic are imported. A total of 366 tonnes of arsenic trioxide was imported in 1975.

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

Asbestos: Australia has large resources of blue asbestos (crocidolite) in the Hamersley Range, WA, and extensive deposits of crocidolite near Wittenoom were worked mainly for export until 1966, when production ceased because of rising costs. There are few known deposits of amosite or of white asbestos (chrysotile). However, a chrysotile deposit at Woodsreef near Barraba, NSW, which contains demonstrated reserves of about 38 million tonnes of fibre-bearing rock, was brought into production in January 1972; output in 1975 was 54 612 tonnes of fibre (exports were 33 284 tonnes). Production is expected to rise to 105 000 tonnes/year of fibre in 1977. A small deposit of chrysotile at Baryulgil, NSW has been exploited for some years, and in 1975 produced 370 tonnes of fibre. The domestic product is dominantly short fibre and although this satisfies local demand and provides exports to Japan, imports of longer fibre chrysotile and of amosite asbestos remain significant. Imports in 1975 were 29 008 tonnes of chrysotile, 12 961 tonnes of amosite, and 6763 tonnes of other varieties, mainly chrysotile fines. Canada and South Africa are the main sources of supply for imported white asbestos. South Africa is also a source of amosite.

Because of its fineness, strength, flexibility and suitability for spinning fibre, white asbestos is the most valuable variety. Blue asbestos, which lacks many of the desirable properties of the white, but is stronger and more resistant to chemical action, continues to be used in some parts of the world in the manufacture of asbestos cement products such as building sheets, pipes, guttering, etc.

Barite: Australia has adequate resources of barite which could be brought to production to meet any domestic requirements for strategic reasons. However, as economic development of deposits of any mineral of low unit value, such as barite and many other industrial minerals, is restricted by transportation costs, domestic requirements in previous years have been met partly by imports. Since 1970, imports have made up from 11-44 percent of estimated domestic consumption which has declined from 14 000 tonnes/year in 1970 to 8700 tonnes/year in 1975, mainly as a result of reduced drilling activity.

Barite's principal use is as a weighting agent in drilling muds and the domestic oil industry accounts for some 90 percent of domestic consumption. Barite is also used as a filler and extender in the paint, varnish, rubber, glass, plastics and paper industries and, because of its high specific gravity, in X-ray - shielding plasters and concretes.

Domestic requirements of barium chemicals are almost entirely imported; the total f.o.b. value of imports in 1975 of precipitated barium sulphate (282 tonnes), lithopone (48 tonnes), barium chloride (47 tonnes), was $234,000.

The scale of barite mining operations in Australia is small; production in 1975 of 23 460 tonnes was from 3 companies and 6 syndicates and individual operators. Over the years South Australia has consistently supplied the domestic market which is concentrated in the eastern States but production, which totalled 6877 tonnes in 1975, has been declining in recent years. Australia's total production was greatly increased in 1975, from 7466 tonnes in 1974, as the result of a new operation in the Pilbara district of Western Australia by Dresser Products Australia Pty Ltd. This company, which commissioned a 50 000 tonnes/year capacity grinding plant at Port Hedland in March 1975, to process output of its North Pole deposit, 110 km east of Port Hedland, established the operation in anticipation of renewed drilling activity on the Northwest Shelf. Although this has yet to eventuate, the company is hopeful that in the interim, its operation will be sustained by export demand. The company reported mine production of 15 207 tonnes in 1975 of which 8720 tonnes was milled; 5200 tonnes of milled barite and 1927 tonnes of crude barite were exported.

Fluorspar: This mineral is essential to the aluminium, steel, chemical, glass and ceramics industries. Consumption is mainly by way of fluorine - bearing chemicals, particularly as aluminium fluoride and synthetic cryolite by the aluminium industry and hydrofluoric acid by the fluorocarbon industry, but in its mineral form it is also used as a flux in steel production, aluminium smelting and in foundries, in glass manufacture as an opacifier, flux and refining agent, and in enamels, fibreglass and welding electrode coatings. In 1975 estimated domestic consumption of fluorspar in its mineral form was 23 500 tonnes of which some 14 000 tonnes was used by BHP, about 9000 tonnes was processed to hydrofluoric acid (at Newcastle and Sydney) and the balance used in the other industries. In addition the fluorspar equivalent of imported aluminium fluoride and synthetic cryolite, used in aluminium smelting, was about 19 500 tonnes.

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

Domestic identified resources of fluorine are substantial mainly because of addition to resources of the 3.5 percent fluorine content of the apatite comprising Australia's large phosphate rock reserves. Total identified resources of fluorine are assessed at 78.21 million tonnes of which 73.14 million tonnes is contained in phosphate rock, 3.87 million tonnes is contained in fluorite deposits and 1.2 million tonnes is contained in fluorite present in low concentrations in accummulated mine tailings at Broken Hill.

Bentonite and Fuller's Earth: The demand for bentonite has risen sharply since 1967 because of increased need for dilling 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 1975, was from Queensland (284 tonnes), New South Wales (2128 tonnes), and Western Australia (938 tonnes), and imports totalled 54 736 tonnes; 18 tonnes of fullers earth was produced in 1975, compared with 78 tonnes in 1974. Deposits of bentonite in various States are being tested, and it is possible that Australian production may rise substantially in the future, although deomestic freight rates present current restraints to exploration of new deposits. The United States and Italy are the main world producers of high quality bentonites, which are in heavy demand for drilling muds.

Diatomite: There are many small deposits of diatomite in Australia, which consumes some 20 000 tonnes annually. Production has been almost continuous since 1896, and amounted to 5543 tonnes in 1975, the shortfall being met from imports. Diatomite is extensively used in filtration processes in the manufacture of foods and beverages, as an insulating medium in furnaces and boilers, and as a light-weight filler for paints, varnishes, and synthetic plastics. The Australian product is not entirely suitable for filtering processes and 13 318 tonnes were imported, mainly from USA, in 1974. Resources for other purposes are adequate. In late 1975, an option agreement between Mallina Mining and Exploration N.L. and the Broken Hill Proprietary Company Ltd concerning diatomaceous earth deposits near Dongara, WA lapsed, and Mallina took over control of the pilot plant. The company estimates that it will cost up to $2.5 million to bring the project into commercial production, and is also assessing diatomite deposits at Wanneroo, immediately to the north of the Perth metropolitan area.

Felspar: Uses are mainly in the glass and ceramics industries and as an abrasive. Australian resources are large and more than enough for any likely requirement. Present centres of production are Mukinbudin and Rothsay, WA, and Broken Hill, NSW, for the potash varieties; and the Olary District, SA, for the potash-soda varieties. Production in 1975 was 3054 tonnes. This could be expanded almost at will, but consumption has declined owing to the greater suitability of nepheline syenite - which is not produced in Australia - for some applications.

Graphite: This mineral has extensive uses as a lubricant, and is employed in many manufacturing processes, for moulding, for graphite crucibles, and in lead pencils. Local production was last recorded in 1963 and so far no high-grade deposits have been discovered in Australia, although possible resources have not been fully investigated. All our requirements are met by imports, which amounted to 983 tonnes in 1975 mainly from China, Korea, and Sri Lanka.

__Gypsum__: Australia's resources are very large, known reserves being in excess of 760 milliontonnes with the probability of a great deal more. The deposits are associated with salt lakes, and occur in the drier parts of South Australia, Victoria, New South Wales, and Western Australia. The chief use is in the manufacture of plaster, cement, and products such as building boards. In 1974 production amounted to 1 068 852 tonnes, of which 303 167 tonnes was exported. As a result of a downturn in the building industry, production in 1975 decreased to 932 638 tonnes, and exports to 215 776 tonnes.

__Limestone, Dolomite and Magnesite__: These have been referred to earlier in connection with metals magnesium and calcium. Resources are very large and production could be increased indefinitely. Limestone is mined in Australia for use mainly in the manufacture of cement, as well as for metallurgical, chemical, agricultural and other purposes. In 1975 limestone production was 10.85 million tonnes. Dolomite production for use in refractories was 450 126 tonnes. Magnesite production was 16 208 tonnes, for use mainly in refractories.

__Mica__: Although Australia's resources are probably large, production, in the face of cheap overseas supplies, is minor. Domestic production of mica in 1975 amounted to 87 tonnes all from Yellowdine, WA.

While the Commwealth Mica Pool operated, during and after the World War II, a series of small mines in the Harts Range in the Northern Territory produced most of our requirement. With the winding up of the Mica Pool in 1960, the market disappeared. Imports in 1975 amounted to 572 tonnes mainly from India, China and South Africa. In the event of an emergency, Australia's domestic industry could probably be revived to meet her requirements. Alternative sources of supply include Argentina, Brazil and Malagasy Republic.

Pigments and Ochres: The term is here used to mean natural earth pigments such as the iron oxides, stained clays, and slate powder which are used to give colour or body to paints, plaster, cements, linoleum, and rubber. A number of small deposits have been worked over the years and Australia undoubtedly has large resources of the iron oxide variety. Some of these are at Wilgie Mia and Weld Range, WA; Rumbalara, NT; Dubbo and Glen Innes, NSW; and the Ulverston-Penguin area of northwest Tasmania. Domestic consumption is very small and there was no production in 1975. Some 10 000 tonnes were imported in 1974-75.

Quartz Crystal - Silica: Australia is self-sufficient in various forms of silica used in glass making, foundry sands, refractory bricks, etc., but there has always been an acute Australian shortage of high quality quartz crystal, which has piezo-electric properties that are extremely useful for stabilizing frequencies in radio communications. Quartz crystal is also used in optical instruments. A wide search made by Government agencies during the war failed to disclose any substantial deposits, and an intermittent search by industry in the years since has met with little success. Since 1952 when production was recorded from near Glen Innes, the only recorded production of quartz crystal has been from Mukinbudin, WA - namely, 70 tonnes in 1974. Imports of quartzite and natural quartz amounted to 1121 tonnes in 1974-75. Recent developments overseas in synthesizing quartz crystal have eased pressure on the need to discover indigenous sources. Some 13 000 tonnes of high-grade silica sand were exported to Japan in 1974-75 mainly from deposits near Cape Flattery, North Queensland, and also from deposits near Perth, WA.

Sillimanite and Kyanite: These minerals are consumed chiefly in the manufacture of high-alumina refractory linings used in furnaces. Deposits of sillimanite are known in several parts of Australia, mostly in remote localities, and currently the only production is from Mount Crawford, SA.

Australian production increased throughout the 1950s and early 1960s to meet increasing demands from industry, but after a peak of 3500 tonnes in 1963 it steadily declined. Production was 751 tonnes in 1974 and 588 tonnes in 1975 and imports were negligible. Imports of kyanite have been greater, and in 1975, imports under an item which included kyanite, sillimanite, andalusite, mullite and dinas earth, totalled 1612 tonnes, mainly from the United States (1038 tonnes) and India (554 tonnes).

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

Salt and Sodium Compounds: Common salt (sodium chloride) can be produced abundantly in certain climatic localities in Australia by evaporation either of sea water or brines of salt lakes and pans. Domestic production increased nearly six fold in the period 1966-1971, from 655 000 tonnes to 3.788 million tonnes, as the result of progressive market entry of new producers producing almost exclusively for export, particularly Japanese needs. All new export-oriented producers established their operations in Western Australia, along the northwest coast - at Shark Bay (Shark Bay Salt), Lake McLeod (Texada Mines Pty Limited), Dampier (Dampier Salt Limited) and Port Hedland (Leslie Salt Co) - except for Lefroy Salt Ltd at Lake Lefroy, 80 km south of Kalgoorlie. The rapid increase in productive capacity, together with slackening export demand in recent years, has led to a situation of over-supply and a situation where each of the producing companies has suffered financial losses from the start of its operations, despite greatly increased salt prices in recent years, from about A$2.90/tonne f.o.b. in 1972 to about A$7.80/tonne f.o.b. since the December 1976 devaluation/revaluation.

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

Total domestic salt production in 1975 was 4.660 million tonnes of which 3.651 million tonnes was exported, virtually all of it from Western Australia. South Australia produced 588 000 tonnes, Queensland 144 000 tonnes and Victoria 92 000 tonnes, for the domestic market. Of total estimated domestic consumption of salt in 1975 of 744 000 tonnes, an estimated 613 000 tonnes was processed to sodium hydroxide and sodium carbonate, 60 000 tonnes was used in other industrial and chemical applications and 71 000 tonnes consumed in food processing, table salt and other preparations.

Despite Australia's position as a net exporter of crude salt, domestic requirements of salt-derived sodium compounds, particularly sodium hydroxide for the processing of bauxite to alumina, are largely met by imports. Australia's capacity to process salt to sodium compounds is constrained by its limited capacity to also consume chlorine, a by-product of the chemical processing of salt. Domestic imports of sodium hydroxide in 1975 were valued at $42.3 million.

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

<u>Sulphur-bearing materials</u>: Commercial deposits of elemental sulphur and sulphur-bearing ("sour") natural gas are not known in Australia and in recent years 50-70 percent of domestic demand for sulphur has been met by imports of brimstone from Canada and the United States, supplemented by occassional shipments from Mexico and Iran. Several oil companies recover sulphur from the processing of imported crude oil; 9603 tonnes of sulphur was recovered from oil refining operations in 1975. Although combined capacity of the 6 recovery plants is about 52 000 tonnes/year of elemental sulphur, actual production depends on the sulphur content of the refinery feedstock and this has been declining since low-sulphur Bass Strait oil replaced high-sulphur imported crude.

Nevertheless Australia has large reserves and resources of sulphurous materials such as pyrites, metal sulphides (ores of zinc, lead and copper and nickel) and gypsum, and in 1975, 56 percent of total domestic sulphuric acid production of 1.143 million tonnes was derived from indigenous material as a by-product of smelting operations at Cockle Creek, NSW, (lead and zinc), Port Pirie, SA, (lead) and Risdon, Tas, (zinc). Sulphuric acid is also produced at Burnie, Tas, from pyrite, as a by-product of copper mining at Mt Lyell and of lead-zinc mining at Read-Rosebery. Small amounts of by-product pyrite are also produced at Mt Morgan, Qld, from copper-gold mining operations there and this material (379 tonnes in 1975) is sold to the domestic glass and steel industries. Recovery of sulphur by Western Mining Corporation Ltd from its nickel refining operations at Kwinana, WA, is an estimated 32 000 tonnes, contained in some 130 000 tonnes of ammonium sulphate.

The recovery of sulphur, as sulphuric acid, from sinter gases of indigenous mineral materials dates back mainly to the early 1950's when brimstone was in short supply and the Federal Government introduced incentives by way of bounty payments, to promote self-sufficiency. Later, when changing circumstances abroad increased the supply situation, the Government announced that bounty payments would not be renewed after June 1965 but, on re-consideration, the Sulphuric Acid Bounty Act was first extended to 1969, then to 1972, when it lapsed. Sulphur is consumed mainly as sulphuric acid, demand for which directly reflects demand for phosphatic fertilizer, particularly superphosphate. Although total domestic acid consumption in 1975 was only 1.144 million tonnes, of which 57 percent was used in phosphatic fertiliser production, consumption in recent years has been around 2.0 million tonnes/year and of which some 80-85 percent was used in fertilizers. The consumption down-turn in 1975 reflected Government's decision to terminate the Phosphate Fertilizer Bounty Act, which provided $11.81/tonne of single superphosphate, from 31 October 1974, but as bounty payments were resumed from 11 February 1976, fertilizer consumption, and consequently acid consumption, are likely to recover to historical levels.

The fertilizer consumption down-turn was especially evident in imports of brimstone; domestic acid production is much less responsive to demand, being only a by-product of smelting operations. Brimstone imports in 1975 totalled 282 000 tonnes, valued f.o.b. at $7.534 million, compared with imports of 685 000 tonnes in 1974 and 587 000 tonnes in 1973.

Vermiculite: This mineral has the unusual property of expanding to many times its original volume when subjected to high temperatures and is used for fire and rot-proofing, as an insulator in electrical and heating equipment, in the manufacture of building plaster, and as a light-weight concrete aggregate. Western Australia is the only state from which vermiculite production is reported. Output, which was sporadic until 1965 when production ceased, resumed in 1970. Production in 1975 was 268 tonnes. A small amount is imported annually (about 3015 tonnes in 1975), South Africa being the main supplier. The United States and South Africa supply almost the entire world production.

Talc, Steatite, and Pyrophyllite: The chief consuming industries are cosmetics, rubber, ceramics, and paint. Small deposits are known in most of the States and, in recent years, Western Australia, South Australia, and New South Wales have been the chief producers. Production of talc in 1975 amounted to 67 242 tonnes of which 45 457 tonnes was exported. Imports, mainly of varieties not available domestically, were 947 tonnes. Production of pyrophyllite from New South Wales totalled 14 990 tonnes. The United States is the leading producer of talc and Japan is the major producer of pyrophyllite, but Australian imports have come from Mainland China, United States, and India, as well as Italy and Norway.

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

Phosphate Rock: Phosphate rock is used almost entirely for the manufacture of superphosphate, production of which, in terms of single superphosphate equivalent, declined to 1.59 million tonnes in 1975, from 5.35 million tonnes in the previous year. The 70 percent downturn reflected consumer reaction to Governments decision to terminate the Phosphate Fertilizer Bounty Act from 31 December 1974, but the sharp downturn was amplified by considerable forward buying in the last months of 1974 to prolong benefits of the effective consumer subsidy of $11.81/tonne of single superphosphate. However, as bounty payments were restored to their previous level from 11 February 1976, consumption is likely to recover to previous levels of some 4 million tonnes/year of single superphosphate.

Production of phosphate rock from northwest Queensland's large deposits, first discovered by BH South in 1966, commenced in April 1975 and although production in 1975 was about 121 000 tonnes, the production rate has, since October 1976, been increased to 1 million tonnes/year.

About half of production is committed to overseas buyers and the company is presently negotiating with the British Phosphate Commissioners (BPC) and local manufacturers to sell the balance domestically, at least up to June 1978, to tide the Company over a period of weak demand worldwide. The company has Government approval to export up to 2 million tonnes/year of rock and is vigorously trying to develop its overseas markets.

A small quantity of phosphate rock is also produced in South Australia but the material is not suitable for superphosphate manufacture, because of its high aluminium and iron content, and, after crushing, is applied directly to the soil by local users; production in 1975 was 2914 tonnes.

Australia's supplies of phosphate rock are drawn chiefly from Nauru and Ocean Island in the Pacific Ocean and Christmas Island in the Indian Ocean. The Christmas Island deposits are owned jointly by Australia and New Zealand and phosphate mining is carried out by the Christmas Island Phosphate Commissioner (CIPC) on behalf of the two Governments. Mining of the Nauru deposits was managed by the British Phosphate Commissioners, on behalf of the Australian, New Zealand and British Governments, to 30 June 1967 when the operation was purchased by the Nauruans. Subsequent to the formation of the Republic of Nauru on 31 January 1968, the Nauru Phosphate Commission was constituted to manage the industry and on 1 July 1970 became fully autonomous, controlling all its operations. Production from Ocean Island is still controlled by the BPC but these deposits will be depleted by the turn of the present decade; reserves of Nauru and Christmas Island are sufficient for some 25-30 years production. Indeed it was the Australian Government's concern for security of future supply of phosphate rock that prompted it to actively encourage exploration for new deposits, both through its own agency the Bureau of Mineral Resources, and private industry, and which ultimately led to the discovery of the northwest Queensland deposits in 1966. Total mainland identified reserves presently exceed 3000 million tonnes of rock of average grade 16.8 percent P_2O_5.

Imports of rock in 1975 totalled 1.981 million tonnes.

Potash: All domestic requirements of potassium salts are imported. In 1975 Australia imported nearly 188 000 tonnes of potassic fertilizers, nearly all potassium chloride, from both Canada and the United States, the f.o.b. value of which amounted to $10.5 million.

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

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

In November 1973 Texada Mines Pty Limited commissioned plant to produce langbeinite ($K2\ Mg_2(SO_4)_3$) from residual brine liquor of its salt (sodium chloride) production operations at Lake McLeod, WA. The project was beset by technical problems, declining export markets and ultimately by flooding. The langbeinite operation has since been put on care and maintenance pending further feasibility studies, and some 10 000 tonnes of material, produced during progressive recommissioning of the plant, is stockpiled at Lake McLeod.

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

Consumption of nitrogenous fertilizers has increased markedly since 1966 when the Commonwealth Government introduced the Nitrogenous Fertilizer Subsidy Act which provides a benefit of $78.74/tonne contained N to consumers of nitrogenous fertilizer. The steady increase of consumption is partly due to the use of nitrogen in new applications especially wheat, other cereals and pasture; although actual quantities of nitrogen consumed in traditional applications to sugar and horticulture have increased, their relative importance is decreasing. The principal N-bearing products applied are urea, anhydrous ammonia, ammonium sulphate and ammonium nitrate. Estimated Australian consumption of contained elemental nitrogen (N) in 1974-75 was 177 600 tonnes. Production statistics for some products are not available for publication, but output in 1973-74 of aqua ammonia (fertilizer and technical grades) was about 33 000 tonnes and ammonium sulphate 246 000 tonnes.

Imports of nitrogenous fertilizers in 1974-75 totalled about 20 000 tonnes which contained an estimated 10 000 tonnes N.

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 1975 the value of imports of refinery feedstock and refined products rose to $733.7 million (crude $489.7 million) from $648.2 million (crude $420 million) in 1974 mainly as a result of increased imports; imports accounted for about 38% of Australian petroleum requirements; indigenous crude oil amounted to about 68% of demand in 1975. The rate of increase in consumption of marketable petroleum products was 1.7% over the previous year, but demand is expected to almost double in the next 10 years. The weighted average annual increase in consumption of the same range of products for the five years ended 31 December 1974 was 5.7 percent.

With the first full year of production from Moonie in 1965 the first step was achieved in the national effort to become self-sufficient. In 1967 output from Moonie, Alton, and Barrow Island was 1.2 million cubic metres (7.6 million barrels); an increase of 124% brought about mainly by Barrow Island coming into production. This represented 5.1% of consumption as compared to 2.7% in 1966. In 1968, Australian indigenous production was 2.16 million cubic metres (13.8 million barrels), in 1969, 2.51 million cubic metres (15.8 million barrels), or 8.8% of total petroleum consumption, and 10.35 million cubic metres (65.1 million barrels) in 1970. Production rose rapidly to 17.95 million cubic metres (112.9 million barrels)in 1971 as the Gippsland Shelf fields came on stream. In 1975 indigeneous crude oil production was 23.8 million cubic metres (149.8 million barrels).

Since the mid 1950s an Australia-wide search has been going on, with mounting intensity in the 1960s. In 1966 some 101 exploratory wells were drilled in Australia (excluding PNG) (compared with 14 in 1959); in 1967 the number fell to 84; in 1968 the total was 97; in 1969 the number of exploratory wells completed was 99, rose to 119 in 1970 and fell to 72 in 1971, rose to 99 in 1972 and fell to 60 in 1973 and to 51 in 1974 to 25 in 1975 and to only 15 in 1976. However, based on exploratory programs announced for 1977 the number of explorator wells could rise, to about 30 this year.

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

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

Crude oil was discovered at Moonie and Alton in Queensland in 1961, and these fields have been producing since 1964. Following this, the Barrow Island oilfield discovery in Western Australia began commercial production in December 1966. The most prolific crude oil discoveries were the Kingfish, and Halibut fields, significant discoveries were made in the Barracouta, Marlin, Mackerel, Tuna, Flounder and Snapper fields in the offshore Gippsland Basin. Commercial production began from Barracouta in late 1969 and was followed by Halibut in 1970 and Kingfish in 1971. The Mackerel and Tuna fields are to be brought into production in 1977 and 1978. At the end of 1976 the production platform at Mackerel had been installed and prepared for development drilling. The Tuna platform has still to be completed and installed.

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

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

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

Production of crude oil and gas from this prolific area began in 1969, and by the end of 1975 crude oil production was some 59 172 cubic metres per day. Natural gas production from this area also began in 1969 and some 2565 million cubic metres were produced in 1975.

Further offshore drilling units arrived in Australia, and by mid-1969 six mobile units were operating in Australian coastal waters. Three of these units were drilling ships, two were semi-submersible platforms, and one was a jack-up unit. In early 1970 five units were operating, and one was idle. However, only 4 offshore rigs were operating in early 1971, 5 in early 1972, 6 in early 1973, 3 were active at the end of 1975. At the end of 1976 two units, Ocean Digger and Ocean Endeavour, both Australian flag units, were in operation. At the end of 1975, some 288 wells were on production in the Barrow Island field, and total daily crude oil production was around 5600 cubic metres per day (35 222 barrels per day). The success of the water flood technique introduced in this field in early 1968 has stimulated production, and it is hoped that this daily rate will be sustained for some time.

The year 1969 saw the completion of three major natural gas pipelines: the 170 km, 30 inch pipeline from Longford to Dandenong commenced delivery to Melbourne and its environs in early 1969, and in the September quarter to 1976 was delivering about 10.5 million cubic metres per day (370.8 million cu. ft./day).

Brisbane received its first delivery of natural gas from the Roma area in March 1969 through the 10 $\frac{3}{4}$ inch, 410 km pipeline. Production from this area in the September quarter of 1976 was being sustained at a daily rate of some 0.72 million cubic metres per day (25.4 million cu. ft./day). At the end of 1976 a pipeline was being completed to connect the Kincora gas field to the main Roma/Brisbane pipeline.

In late 1969, Adelaide received natural gas through the 22 inch 778 km pipeline from the Gidgealpa - Moomba field. Production through this line was some 5.44 million cubic metres per day (192.2 million cu. ft/day) in the September quarter of 1976. Natural gas was delivered to the Perth area from the Dongara field in October 1971 which is currently delivering gas at a rate of 2.3 million cubic metres per day (81.2 million cu. ft/day). The natural gas line to Sydney from the Cooper Basin fields in South Australia wasbrought into service in late 1976 with natural gas being supplied to Sydney consumers in late December.

In 1976 indigenous crude oil production from proven fields supplied about 68% of Australia's requirements. However, the crude oils discovered so far are deficient in the heavier distillation fractions required by heavy industry and road and paving construction, and thus import of crudes rich in these fractions must continue, at about 30% of total consumption, until an adequate source is found in Australia. Also since national consumption on average is increasing at about 4% per year, further substantial Australian discoveries are essential in order to maintain or reduce the deficit gap between indigenous production and importation.

Should we not be successful in establishing additional petroleum reserves within our own boundaries, it will be necessary to turn our thoughts to other and less convenient source materials for fuel, and to other sources of power such as uranium. Petroleum can be distilled from oil shale, and some attention is now being directed to our shale deposits, particularly those in Queensland; on the other hand our very extensive resources of coal may provide an alternative source if economic methods of synthesis can be developed to suit them. A great deal of attention has been given, for several years, to setting up the research facilities necessary to examine all possibilities connected with making full use of our coal, and a good deal more is being done in this regard than is generally realized. The USA has already advanced far, both in research and applied technology, in this field.

THE ROLE OF GOVERNMENT IN ASSISTING MINERAL EXPLORATION AND DEVELOPMENT

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

The Commonwealth undertakes all topographic mapping within its own territories and is active in most States. Commonwealth agencies are the Division of National Mapping (Department of National Resources), which has the primary responsibility, and the Royal Australian Survey Corps (Army), which does a substantial amount of work, making available those of its resources that are not required solely for military purposes.

The aim of the topographical mapping program is to prepare maps at a scale of 1:100 000 with 20-metre contours. For about one-third of Australia, the populated areas and the coastal fringe, line maps are published at this scale, of which about half are now available. For the central portion, orthophoto-maps with 20m contours will be published at 1:100 000, backed up with line maps at 1:250 000 (contour interval 50m), which will eventually cover the whole of Australia. There is a complete interchange of data between National Mapping and the Survey Corps to minimise cost, and two editions are published, one for military use and one for civilian use. The latter is distributed by the Department of National Resources. Additionally, mapping at larger scales is produced by the States, and by the Army for training purposes. National Mapping also maintains a 1:10 000 series of all populated places of more than 150 people, primarily for census collection 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 is several times as long at least. However, over 90 percent of the continent has been covered since World War II, and mapping is expected to be completed by 1980.

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

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

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

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

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

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

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

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

TABLE 1. VALUE OF EXPORTS BY INDUSTRIAL GROUPS

	1971/72		1972/73		1973/74		1974/75		1975/76	
	Value (f.o.b. $'000)	%	Value (f.o.b. $'000)	%	Value (f.o.b. $'000)	%	Value (f.o.b. $'000)	%	Value (f.o.b. $'000)	%
Industrial Groups -										
Agriculture	961 800	20.5	831 315	14.0	1 112 895	16.7	2 257 736	27.0	2 105 953	22.7
Pastoral -										
Wool	582 208	12.4	1 130 467	19.0	1 156 564	17.3	753 492	9.0	961 979	10.4
Other	698 754	14.9	1 128 266	19.0	1 023 457	15.3	626 700		913 276	9.9
Dairy and farmyard	120 597	2.5	164 445	2.8	165 042	2.5	173 896	2.1	212 971	2.3
Mines and quarries (other than gold)	1 100 814	23.5	1 252 386	21.1	1 563 608	23.4	2 253 596	26.9	2 651 741	28.6
Fisheries	75 634	1.6	75 508	1.3	68 941	1.0	71 331	0.9	83 474	0.9
Forestry	7 367	0.1	9 139	0.2	11 058	0.2	12 085	0.1	11 674	0.1
Total Primary Produce	3 547 174	75.5	4 590 526	77.3	5 101 568	76.5	6 148 836	73.5	6 941 068	74.9
Manufactures	985 815	21.0	1 204 980	20.3	1 380 504	20.7	1 933 341	23.1	1 991 517	21.5
Refined petroleum oils	57 784	1.2	43 144	0.7	100 817	1.5	157 443	1.9	159 636	1.7
Unclassified	106 348	2.3	98 515	1.7	89 963	1.3	128 135	1.5	173 546	1.9
Total Australian Produce	4 697 121	100.0	5 937 165	100.0	6 672 852	100.0	8 367 756	100.0	9 265 766	100.0

SUMMARY OF ORE RESERVES AND MINERAL PROCESSING

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

Very large - sufficient for more than 100 years ahead

Large - sufficient for 30-100 years ahead

Adequate - sufficient for 15-30 years ahead

Small - sufficient for 5-15 years ahead

Very small - less than 5 years ahead

In some cases, the uncertainty of reserves is indicated.

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

TABLE 2 SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

1975

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

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

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

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

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

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

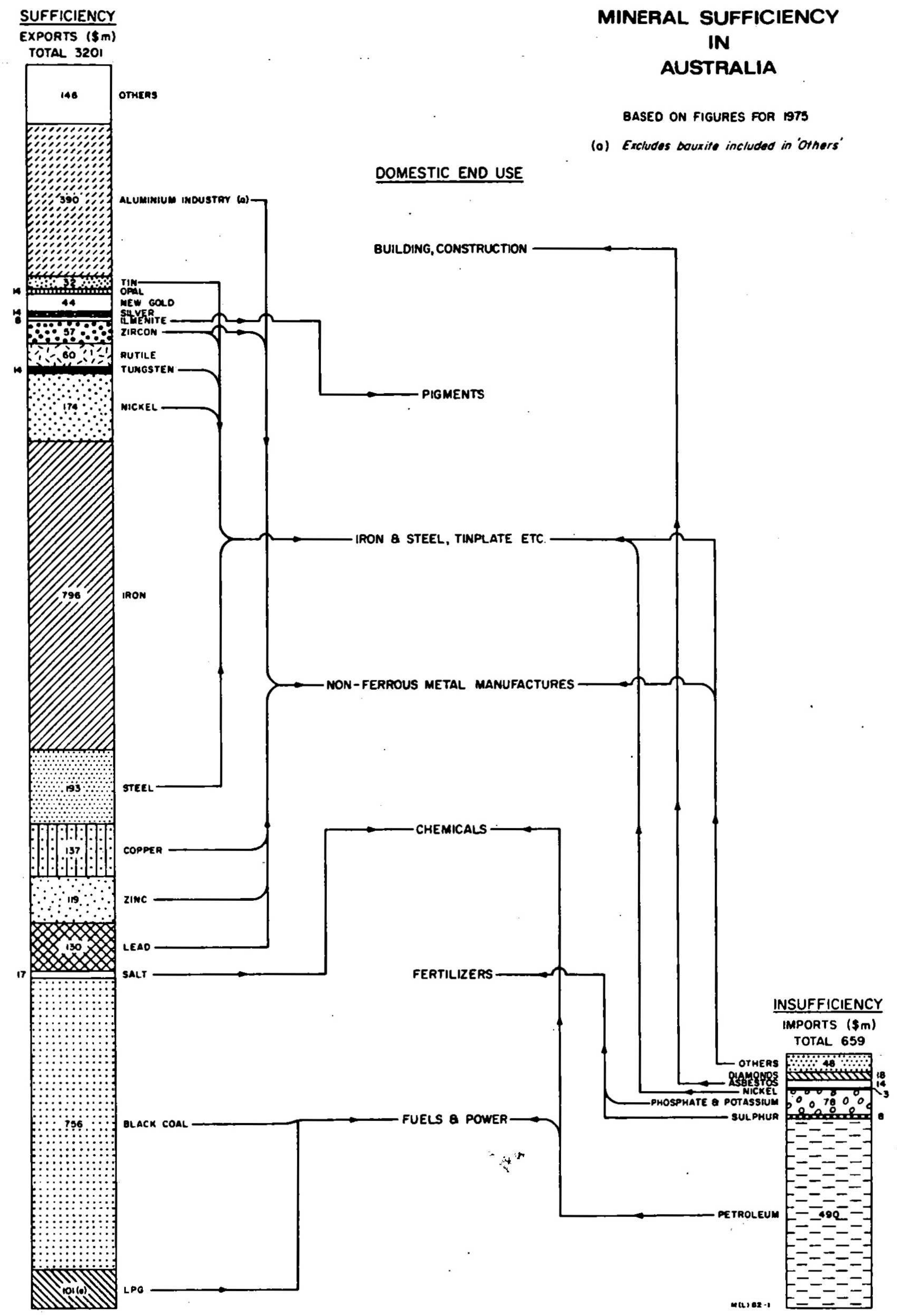
Availability of Supply				Mineral Processing			
Metal or Mineral	Distribution	Domestic Identified Resources	Current Raw material Imports	Level of Processing	Distribution	Current Imports	Possible Disadvantages in Emergency
Light Metals							
Aluminium	Northern and SW Australia	Very large	-	Alumina and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

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

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

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

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



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