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MINERAL RESOURCES OF AUSTRALIA

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by

MINERAL COMMODITIES BRANCH

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TABLES

ABSTRACT

The minerals industry has made an important contribution to the Australian economy since the mid 1800s, and in the last 20 years it has expanded severalfold. It now plays a fundamental role in the Australian economy and has become an equal partner with the agricultural-pastoral industries as a mainstay of our economy and export trade. The annual value of mine production is now about $16000 million and Australia's favourable annual balance in mineral trade is about $9100 million.

This paper first summarises the development of the Australian mineral industry, which is divided into four stages - early settlement and exploration from 1788 to 1851, establishment of the mineral industry from 1851 to about 1910, the lean years of exploration and development from 1910 to about 1950, and the large and varied developments leading from discoveries made since then. The broad spectrum of minerals mined in Australia is then described, under the general headings: energy minerals, iron and ferroalloys, base metals, other metals, and non-metallic minerals.

Australia is now a leading world producer and exporter of many minerals, and in most cases this is based on extensive resources. Before World War II Australia had a long list of mineral deficiencies. As late as 1965 the value of mineral trade was barely in balance, but now the value of exports is more than five times as great as that of imports. Coal, iron ore, and the products of bauxite mining account for about 65% of the value of mineral exports; oil continues to be our most costly mineral import and accounts for about 81% of the value of mineral imports. At this stage, elemental sulphur seems to be our only true 'geological' mineral deficiency. Other major mineral imports (asbestos, phosphate rock, and ferroalloys) reflect 'economic' rather than 'geological' deficiencies.

Government has assisted the development of the mineral industry by providing topographic, bathymetric, geological, and geophysical maps; through bounties, subsidies, and taxation concessions; and by stockpiling. However, notwithstanding Government assistance and a rich natural mineral endowment, vigorous exploration and development programs must be maintained if the industry is to continue as a major industrial section of the economy, and a major source of supply of minerals, processed and unprocessed, to world markets.

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INTRODUCTION

This paper 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. We should like to acknowledge the assistance of officers of the Petroleum Branch, the Mineral Project Evaluation Branch, the Division of Continental Geology, and particularly Mr A.G.L. Paine of the Publications and Information Section for his editorial assistance.

The topic of mineral resources is a large one. Australia's known mineral wealth has increased with every decade since the first major discoveries more than a century ago. Our growth as a nation has owed much in the past to the flow of 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 three decades in the wake of exciting discoveries from which great new sources of wealth have emerged.

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 rivalling the rural industry as a mainstay of our economy and export trade.

Statistics available do not indicate the real contribution of the mineral industry to G.D.P. but the value of exports by industrial groups given in Table 5, 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 1984/5 to all exports was 30%. However the contribution of the mineral industry was in fact higher because the industrial classification used in Table 5 allocates exports by the smelting and refining sections of the industry to 'manufactures'. For example, if the value of alumina is added to mineral exports the contribution rises to 35.5%.

However, the mineral industry cannot be seen in perspective without identifying problems as well as achievements. If the current high level of self-sufficiency in crude oil is to be maintained, additional reserves must be delineated; this will require large amounts of capital for exploration and development; restricted domestic markets for processed products, amongst other factors, continue to place restraints on mineral processing; domestic cost increases, relative to those overseas, have eroded our competitiveness and discouraged some new developments; and the prosperity of the industry, inevitably based on exports, although benefitting from long-term contracts remains heavily dependent on the Japanese economy, which currently provides markets for 39% by value of our mineral exports. Indeed the temporary slowing down of the Australian mineral industry from 1977 to 1980, as a result of lower world metal prices and of checks to the economies of both USA and Japan in particular, serve 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 the boom years of the late 1960s and early 1970s tended to exaggerate the situation and to obscure the fact that in terms of development and production the industry continued to rise. The level of exploration expenditure, in real terms, increased every year from 1976 to 1981; this trend was reversed in 1982 for non-petroleum exploration expenditure which declined in both money and real terms, and has continued to decline to June 1985, the last date for which expenditure statistics are available. Expenditure on exploration for petroleum increased seven-fold in real terms from 1977 to 1982, but fell in the next two years. A continued high rate of exploration is needed to find resources to replace those extracted, and if Australia is to be able to make proper assessments of its resources.

Another factor affecting the industry is the concern about environmental matters accompanied by delays and additional costs in some mining developments, and likely permanent loss of identified resources to mining, particularly those of mineral sands along the east coast. Moreover, new emphasis on aboriginal land rights has been claimed to be slowing down mineral exploration and development in some areas.

Table 6 includes a summary of mineral resources and of the extent of mineral processing in Australia. Overseas trade in minerals and mineral sufficiency, showing values of imports and exports of minerals in 1984, are illustrated in a diagram facing page 1.

The minerals discussed are grouped under the following headings -

(a) Energy minerals: petroleum, uranium, coal, and oil shale
(b) Iron, manganese, nickel, chromium, and other metals commonly used in the manufacture of steel
(c) Base metals: copper, lead, zinc, tin
(d) Other metals
(e) Non-metallic minerals

Tables 1 to 4 show production and trade statistics for the Australian mineral industry. Mineral statistics given are those for 1984, the latest calendar year for which complete figures are available.

DEVELOPMENT OF THE MINERAL INDUSTRY

The Australian mineral industry started with the first quarrying and shaping of Hawkesbury Sandstone for early buildings at Sydney Cove and when the first settlers dug clay for brickmaking. Its development can be conveniently divided into four stages - early settlement and exploration, from 1788 to 1851; establishment of the industry, from 1851 to about 1910; the lean years, from 1910 to about 1950; and the large and varied developments leading from discoveries made since the beginning of the 1950s.

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 including the level of technology in exploration, mining and treatment, and such matters as government policies and the emergence of markets.

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Early settlement and exploration, 1788-1851

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 that contained coal 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 later and mining started near Newcastle in 1799. 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 the 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 resulting from geographical exploration during this period were largely in the field of botany rather than geology. And, 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 metal mines did not open until the 1840s. Silver-lead ores were mined in 1841 near Adelaide, and copper ore at Kapunda in the same general area in 1842. In the same decade the first pig iron was produced from a small deposit of iron ore at Mittagong near Sydney, although the enterprise found great difficulty in competing with imported material and eventually ceased operation in 1877.

Establishment of the industry, 1851-1910

It was the discovery of payable alluvial gold near Bathurst, NSW, 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 all profoundly influenced the development of Australia from the 1850s onwards.

It was not long before new interest and expertise in prospecting, arising from the succession of gold discoveries, led to the finding and exploitation of other metals. The start of tin mining in 1872 almost simultaneously at Inverell (NSW), Stanthorpe (Qld), and Mount Bischoff (Tas.) heralded very considerable tin production in eastern Australia, which became the major world source of tin for nearly a decade in the late 1870s and early 1880s. Copper mining was rejuvenated by discoveries at Cobar, NSW, in the early 1870s and the finding of Mount Morgan, Qld, in 1882 and of Mount Lyell, Tas., in 1885; although Mount Morgan and Mount Lyell were first mined for gold, by the close of the century they had been shown to contain large reserves of copper ore too. The mineral industry was further diversified with the discovery of the rich lead-zinc-silver lodes at Broken Hill, NSW, 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 1892 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 of exploration and discovery, 1910-1950

The mining industry continued to prosper in the early years of the twentieth century, but fortunes 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 1930s. During these lean years, significant new mineral discoveries were restricted to lead-zinc-silver and copper at Mount Isa, Qld, in 1923 and 1930 respectively and scheelite (an ore of tungsten) on King Island, Tas. in 1925. Only lead, zinc, and silver production and exports, based on Broken Hill and Mount Isa, showed a 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 copper continued, and output of refined pig lead substantially increased in the second decade and was joined by refined tin and by significant increased in output of refined zinc after 1917. Mineral 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, and 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 examples were the development of differential flotation for the separation of lead and zinc sulphides from Broken Hill ores and, later, the electrolytic refining of zinc sulphides to pure metal, in the early part of the 20th century. Basically the same flotation process has been used in the treatment of sulphide ores around the world ever since.

The 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, NSW, in 1875 and based on local coal supplies, provided the basis 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 ports 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 steelworks on the coast at Newcastle, NSW in 1915 and, although faced with problems in both the 1920s and the 1930s, steelmaking was firmly established and began to expand. Another enterprise, G. & C. Hoskins, eventually transferred steel-making from Lithgow to the coast near Wollongong in 1928, but subsequent trouble in the depression in the early 1930s led to this project being taken over by The Broken Hill Pty Co. Ltd in 1932. In 1919 the Victorian Government passed legislation to establish the brown coal industry in the Latrobe Valley, based on large deposits discovered 30 years earlier.

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 coal as fuel in all States, had bolstered the economy about the turn of the century, and continued to provide steel, 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 M t, was a reaction of the Commonwealth Government to this concern.

The industry in modern times

It is therefore all the more remarkable that within the next decade, starting with the discovery of uranium at Rum Jungle in 1949, there began a series of ore discoveries that is still continuing and that has far exceeded any previous mining boom in Australian history.

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

It is interesting to note how technological progress has changed the pattern of mineral discovery in Australia since the 1930s. 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 war, although prospectors and others still make discoveries, the emphasis has shifted to the scientific exploration team, and an indirect, conceptual approach to mineral exploration.

The mineral industry has resumed its old role of opening up the country with railway lines, roads, ports, and towns, has added oil and natural gas to Australian fuel supplies, and has provided processed aluminium and nickel for Australian industry. The long list of significant mineral insufficiencies of the late 1930s has been reduced to sulphur; economic considerations have either limited or deferred development of known resources of some minerals such as asbestos, chromite, phosphate rock and potash. Production of diamonds, hitherto on the mineral deficiency list, began in the Kimberleys in 1983.

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 exports of mineral primary products has risen from $69 million in 1950 to $11 224 million in 1984, to provide currently about 42% of Australia's overseas earnings and to surpass the combined agricultural and pastoral industries as Australia's largest export earner. 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 $9158 million in 1984 and will undoubtedly continue to increase for several years yet.

The rise of the mineral industry was timely, happening when wool and most other rural industries were in difficulties, and doubtless saved Australia from currency devaluation and import restrictions in the late 1960s. Reserves of iron ore, coal, and bauxite, which now account for about 65% of Australia mineral exports, are very large and, combined with long term contracts, promise continued major production and exports. Added to this, exports of crude oil have begun and export of natural gas is in prospect within the next few years.

However, the 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 small population. Moreover, since mineral resources are wasting assets, a continued flow of risk capital is required in the future to replace depleted resources, particularly of crude oil if Australia's high level of self-sufficiency in oil is to last. Australia was shielded to a large extent from the world crude oil crisis in the 1970s by the level and prices of domestic supplies.

Inflation in Australia has increased the cost of exploration, development, and production, reduced profitability, increased cut-off grades, and discouraged new developments, particularly where world metal prices, such as those for copper, have not increased in real terms. The recent world economic recession added to the industry's problems because of its dependence on exports.

The late 1960s 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; as a result the mining industry no longer operates with the degree of isolation from the rest of the community that was evident in previous years.

ENERGY MINERALS

Petroleum*

Australia's main mineral deficiency has long been that of indigenous petroleum, particularly crude oil, the lack of which has compelled it to import significant amounts of crude oil and refined products to meet domestic consumption. In 1984, petroleum production reached record levels: output of crude oil increased by 18%, natural gas 6%, LPG 10% and condensate by 44%. Refinery output increased nearly 3% and input from indigenous sources 76%. Domestic consumption (sales) of most products rose but was below the level of previous years. The total value of imported petroleum and its products rose by 1% to $2247 million but the value of imported crude oil fell by nearly 14% to $1072 million. Exports of petroleum and its products rose by 30% in value to $2057 million, mainly due to substantial shipments of crude oil and condensate begun in late 1983.

Since the mid-1950s an Australia-wide search for oil has been going on. In 1965, 156 exploratory wells were drilled in Australia, compared with only 14 in 1959; in succeeding years the number has ranged from a low of 19 in 1976 to a record 269 in 1985. Based on announcements of future programs, the estimated number of exploratory wells to be drilled in 1986 is 240.

Part of the reason for the increased tempo of petroleum exploration in Australia in the 1960s undoubtedly resulted from the Commonwealth's policy of subsidising private companies' expenditure under a scheme introduced in 1958 and terminated in June 1974. Under this scheme selected operations were at first

*Prepared by Petroleum Branch, BMR

reimbursed by 50 percent (later reduced to 30 percent) of the cost. The then Commonwealth Government did not renew this subsidy scheme after June 1974, but established a Petroleum & 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 & Minerals Authority was invalid.

Incentive was, of course, increased by the commercially viable oil and gas discoveries made in the early 1960s and before the decline in drilling activity in the mid 1970s. These include the gas fields in the Roma area in Queeensland and the Kincora and Boxleigh-Silver Springs gas fields now supplying Brisbane with natural gas; the Gidgealpa-Moomba-Big Lake-Della and Namur gas and condensate fields (Cooper Basin) in South Australia, now supplying Adelaide and Sydney with natural gas; the Gippsland Shelf major gas/oilfields, Barracouta and Marlin, supplying gas to Melbourne; the Dongara area fields in WA and Northwest Shelf gas, supplying Perth; and the Palm Valley and Mereenie fields in NT now supplying Alice Springs power station and the soon to be completed mini-refinery. Several major discoveries of natural gas on the Northwest Shelf and in the Bonaparte Basin are being appraised and production plans assessed.

In September 1975 the incentive to explore was further increased by the Government's "new oil" pricing policy with the introduction of world parity price for "new oil" discovered after 14 September 1975. This policy was amended in 1976 so that "new oil" received the full import parity price free of any excise and this arrangement is still in force in early 1986.

Oil was discovered at Moonie and Alton, Qld, in 1961 and these fields have been producing since 1964. The Barrow Island oilfield, WA, began commercial production in December 1966. The most prolific oil discoveries were the Kingfish and Halibut fields in the Gippsland Basin in Bass Strait; significant discoveries were made also in the Barracouta, Marlin, Mackerel, Tuna, Flounder and Cobia fields and more recently at Fortescue in the same basin. Commercial production of gas began from Barracouta in late 1969 and was followed by oil from Halibut in 1970, Kingfish in 1971, Mackerel in 1977, and Tuna in 1979. Since then a further 4 fields have been brought into production, the latest being the Flounder oilfield in December 1984. Although oil production from these latter fields will not greatly increase the normal level of production, it will help maintain it for several years as the production rate from the older fields begins to decline. In 1985 plans were announced for a $1800 million third-phase development of the Bass Strait oil and gas fields and work commenced on a production platform for the Bream oil and gas field due for completion in mid-1987.

In October 1984, the Federal Government introduced special excise arrangements to encourage development of a number of 'old' oil fields which were considered uneconomic for development. These fields are classified as Substantial New Developments and attract an 'intermediate' excise rate for their production. Many of the newly proposed Bass Strait oil and gas fields fall within this initiative.

A small offshore platform at the Harriet oil field, near Barrow Island, WA, was substantially completed by the end of 1985 and production is expected to commence in early 1986. The Jabiru oilfield in the Timor Sea is expected to be completed in mid-1986 with the installation of a sub-sea production wellhead. This development will be the first project to proceed under the Federal Government's Resource Rent Tax which took effect on 1 July 1984 and applies to offshore areas

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under the jurisdiction of the Petroleum (Submerged Lands) Act other than in specified areas and those excluded areas where production licences were granted before 1 July 1984.

The first offshore rig, the Glomar III drill ship, was brought to Australia in 1964. With its first well, Barracouta No 1, it discovered gas and what is now known as the Barracouta field, some 50 km from the Gippsland coast of Victoria. More offshore drilling units arrived in Australia, and by mid-1969 six mobile units were operating in Australian coastal waters. At the end of 1985 seven mobile offshore units were active in Australian waters and four platform rigs were also active on the Fortescue, Flounder, and Harriet fields and on the North Rankin 'A' platform, Northwest Shelf.

The year 1969 saw the completion of three major natural gas pipelines. The 170 km (760 mm diameter) pipeline from Longford to Dandenong first delivered gas to Melbourne and its environs in early 1969, and in 1985 was delivering gas at a rate of about 14.5 million m^3/day. Brisbane received its first delivery of natural gas from the Roma area in March 1969 through a 270 mm diameter, 410 km pipeline. Production during 1985 from this area, together with that from the Kincora and Boxleigh-Silver Springs fields, was being delivered at a rate of 1.3 million m^3/day. In late 1969, Adelaide received natural gas through a 560 mm 778 km pipeline from the Gidgealpa-Moomba field.

The natural gas line to Sydney from the Cooper Basin fields in South Australia was brought into service in December 1976. The average rate of gas production from the Coooper Basin fields (for Adelaide and Sydney) during 1985 was about 13.4 million m^3/day. At the end of 1982 a liquids pipeline had also been built from the Cooper Basin fields to Port Bonython on Spencer Gulf, from where LPG and condensate export shipments began in August 1983. In 1984 a 780 km (323 mm diameter) liquids pipeline from Jackson to Moonie was completed to service new fields in southwest Queensland.

Australia currently meets about 80% of its petroleum product needs from indigenous oilfields. However, the crude oils discovered so far have been deficient in the heavier distillation fractions required by heavy industry as well as for road and paving construction and as lubricants. The Bureau of Mineral Resources estimates that total production from known and undiscovered fields could supply between 56% and 86% of demand in 1993-94. There would be an 80% chance of achieving the 56% level of self-sufficiency and only a 20% chance of the 86% level.

Should Australia fail to find more petroleum, then it would become necessary for it to rely on other and less convenient source materials for fuel, and other sources of energy such as uranium, coal, and oil shale. A petroleum substitute can be extracted from oil shale, and attention is now being directed to such deposits, particularly in Queensland; Australia's very extensive resources of coal could also provide a possible alternative source if economic methods of conversion are developed. Research into coal conversion is now active in Australia and abroad, especially USA and West Germany.

The Commonwealth contributes to the exploration process in Australia by carrying out, through BMR, regional geophysical surveys and geological research related to Australia's sedimentary basins and the origin of petroleum.

Uranium

Australia is not a consumer of uranium, although small quantities of enriched uranium are imported for use in research and production of radioisotopes in the atomic reactor at Lucas Heights, near Sydney. In Australia there have been two periods of uranium production, the first between 1954 and 1971 and the second from 1976 onwards. Since 1976, Australia has progressively become an important producer and exporter of uranium oxide.

The national search for uranium deposits began in 1944 and resulted in the discovery of Rum Jungle in 1949 and of Mary Kathleen in 1954. Small deposits were also 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 area, NT, in the early 1950s.

During the first period of uranium production, treatment plants were erected at Port Pirie, SA, where for several years high-cost material was produced from ores mined at Radium Hill; in the Northern Territory at Rum Jungle, where the plant remained in operation treating stockpiled ores until 1971; at Moline and Rockhole, also in the Northern Territory; and at Mary Kathleen, Qld, which began operating in 1956, was placed on care-and-maintenance in 1963, resumed production in 1976, and was closed down permanently in 1982.

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 were arbitrarily established by Government agreement. In retrospect, the prices secured by Australia in several of its long-term contracts turned out to be very favourable. However, 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.

In 1967 the Commonwealth Government relaxed its embargo on uranium exports and the growing need for uranium for nuclear power purposes stimulated exploration, which met with notable success. Large deposits were discovered at Ranger, Nabarlek, Koongarra and Jabiluka, about 230 km east of Darwin, confirming the existence of a major uranium province in the Alligator Rivers area. New discoveries were also made in the Frome Embayment, SA; at Yeelirrie and Mulga Rock in Western Australia; and several small deposits in the Ngalia and Amadeus Basins in the Northern Territory. In Queensland, new discoveries were made at Maureen and Ben Lomond and in the Westmoreland-Pandanus Creek area near the Qld-NT border.

In South Australia the Olympic Dam copper/uranium deposit was discovered by Western Mining Corporation on Roxby Downs Station in 1975. A significant intersection of uranium at the Acropolis prospect, 25 km southwest of Olympic Dam, further enhanced the potential of the Stuart shelf region, west of the main Adelaide Geosyncline.

As at 31 December 1985, BMR assessed Australian resources of uranium in the reasonably assured category, and extractable at costs up to $US80/kg to be 465 000 t U, representing 29% of the world's uranium resources in that category.

Uranium oxide is currently being produced from two operations. Queensland Mines Ltd mined the entire orebody at Nabarlek in 1979; the stockpiled ore is being treated on-site (capacity of the treatment plant is 1080 t/year U_3O_8). Energy Resources of Australia Ltd commenced production from the Ranger deposit in 1981. Mining is by open-cut methods and the treatment plant has a rated capacity of 3000 t/year U_3O_8. The mine has sufficient reserves to last approximately 30 years at current production rates.

Western Mining Corporation announced that drilling at the Olympic Dam deposit had defined probable reserves of 450 Mt averaging 2.5% Cu, 0.8 kg/t U_3O_8, 0.6 g/t Au and 6.0 g/t Ag. Following the completion of an extensive feasibility study, the joint venturers stated the project is commercially viable at an annual production of 55 000 tonnes of copper, 2000 tonnes of U_3O_8 and 90 000 ounces of gold. A commitment to the project was announced in December 1985 and construction is expected to commence in the first half of 1986.

Feasibility studies and environmental impact statements have also been completed for several uranium deposits including Jabiluka and Koongarra in the Northern Territory, Yeelirrie and Lake Way in Western Australia, Beverley and Honeymoon in South Australia, and Ben Lomond in Queensland.

World demand for uranium increased sharply between 1974 and 1976, with spot prices increasing from $US7.70/lb U_3O_8 in early 1974 to a maximum of $US43.40/lb in mid-1978. The spot price remained above $US40 until the end of 1979, but has since fallen, recording a low of $US14.25 in April 1985 and rising to $US17.00 in December 1985.

Black Coal

The last two decades have seen a spectacular increase in the growth of the Australian black coal industry. The main catalyst for this growth was originally the coking-coal export market but in recent years thermal coal has been the main contributor to increased coal exports. As a result of increased world demand for Australian coal, new mines were developed in both Queensland and New South Wales. This development phase is completed and there is little prospect for the development of many new mines in the next few years, with increased demand being met by incremental expansion of existing mines or utilisation of idle capacity. Australia's largest, and economically most important, deposits of black coal are concentrated in two main areas: the Bowen Basin in eastern Queensland and the Sydney Basin in New South Wales. More than 85% of Australia's demostrated economic resources of black coal are in these two areas.

In 1984 Australia became the seventh largest black coal producing nation, accounting for almost 4% of world production of saleable coal. Australian raw coal production rose by 17% to 139.1 Mt which yielded a saleable coal output of 114.8 Mt, 16% higher than in 1983.

The State producing the largest amount of coal is New South Wales, accounting for 49% of raw coal production in 1984. The growth of production of raw coal in Queensland accelerated rapidy in 1984 and the State produced 47% of the national output of raw coal. Growth in Queensland production has been based on the development of large-scale open-cut mines, initially for coking coal but more recently for steaming coal; over 90% of Queensland's raw coal output comes from open-cut mines. The bulk of production comes from the Bowen Basin in eastern Queensland; most of the coal produced is still low to medium volatile coking coal for export but steaming coal is becoming increasingly important. Smaller quantities of non-coking coal are mined at or near Callide, Ipswich, and Maryborough for use by electric power stations or local industry. Steaming coal mined in the Bowen Basin is used in domestic industries and some is exported. In addition, some semi-anthracite is produced at the Yarrabee open-cut mine near Blackwater.

Coal mined in New South Wales is bituminous and nearly all is mined in the Sydney Basin. In 1984, underground mines accounted for 62% of raw coal production. About 63% of total New South Wales production is high-volatile soft-coking coal and steaming coal, most of which is mined in the Singleton-North west, Newcastle and South Maitland Districts; smaller quantities are mined in the Western District near Lithgow. The soft-coking coal is used to produce coke for the Newcastle steelworks or is exported. At the present time most of the steaming coal is consumed locally for electric power generation and local industry, but in recent years the quantity of steaming coal being exported has increased substantially.Low-volatile and medium-volatile hard-coking coals (i.e. premium grades), are mined in the South Coast and in the Burragarong Valley Districts. About one-fifth of this coal is used at the Port Kembla steelworks and for the manufacture of coke at other plants, a small amount is shipped to the Newcastle steelworks, and the rest is exported. In 1984, 1.1 Mt of coking coal was shipped from Port Kembla to Whyalla.

Small quantities of coal are mined at Gunnedah in the Singleton North West District and at Ashford in northern New South Wales.

Comparatively small amounts of non-coking coal are mined in other States for use by electric power stations or local industry. Non-coking coal is obtained from the open-cut mine at Leigh Creek (SA) and from underground and open-cut mines at Collie (WA), and from underground mines near Fingal in Tasmania.

In 1984, consumption rose by almost 3 Mt to 39.8 Mt; increases were recorded for electricity generation, the production of iron and steel and for alumina refining. Consumption in electricity generation accounted for 72% of total consumption, and the iron and steel industry for 16%.

Australia is a major exporter of black coal. In 1984 it became the world's leading exporter, accounting for about 25% of world trade. Coal was Australia's largest single export earner. Exports were made up of 28.9 Mt of steaming coal and 47.0 Mt of coking coal.

Exports to Japan rose by 14% to 41.0 Mt in 1984. The remaining coal was exported mainly to Europe and Southeast Asia.

The substantial improvement in outlook for world crude oil supplies and lower prices has tempered forecasts of growth in demand for steaming coal. Growth in demand for coking coal continues to be slow and its magnitude will depend on continued world economic recovery. Only a limited number of countries had the potential to substantially increase their coal export capacities in 1984 to meet the projected growth in requirements. For coking coal Australia, USA, and Canada had the greatest potential, whilst for thermal coal Australia, USA and South Africa had the greatest potential. As much of the additional capacity had been committed in anticipation of an increased demand, the slowdown in demand has led to an excess of capacities in these countries. Thus until demand improves the Australian industry will experience difficulties maintaining export tonnages and prices. Australia's known resources are sufficient to allow it to continue as a major exporting country for many decades to come.

Brown coal

Australia's major economic deposits of brown coal (more than 98% of economic demonstrated resources) occur in Victoria. Deposits are also known at many places along the southern margin of the continent and as far north as central Queensland. However, except for deposits in Gippsland, and at Bacchus Marsh and

Anglesea in Victoria, several deposits in South Australia, and the deposit near Esperance, Western Australia, known deposits are currently uneconomic as sources of energy for a variety of reasons including depth of cover and high salt content.

Because brown coal has relatively low specific-energy and a high water content, its utilisation depends on large-scale, low-cost mining, and negligible transportation costs in its raw state.

In Victoria, the only State which produces brown coal, the industry has reached a high degree of sophistication in mining, on-site power generation, briquette production and char manufacture. About 96% of the State's output in 1984 was produced by the State Electricity Commission at Yallourn and Morwell and the rest by privately-owned mines at Anglesea and Bacchus Marsh. Because brown coal may ignite spontaneously if stockpiled, producers and consumers do not accumulate large stocks, consequently consumption is roughly equivalent to output.

The major market for brown coal is power generation. Minor markets are linked to solvent-refined coal, activated carbon and char production. Investigations are continuing to determine the liquefaction potential of various Victorian brown coal deposits.

Australia's known resources of brown coal are very large and greatly expanded production would be possible subject only to market, environmental, and capital limitations.

Oil Shale

Triggered by the first major increase in the world crude oil price in 1973, interest was revived in oil shale as a potential source of liquid fuels. However, this interest waned a little because of weakening oil prices and rapidly increasing capital costs of processing plants. Exploration in the 1970s, especially in Queensland, has resulted in the discovery of extensive resources.

Oil shale is a fine-grained sedimentary rock containing organic matter that yields substantial amounts of oil when heated in a closed retort. Intermittent production took place from some Australian deposits in New South Wales (e.g. at Glen Davis and Joadja) and, to a lesser extent, Tasmania from 1865 until 1952. The most intensified production was during a period of oil shortage and rationing during and after World War II; total production during this period amounted to about 230 000m^3 (1.4 million bbl) of shale oil.

Australia's inferred subeconomic resources of oil shale are estimated to be capable of yielding 40 600 million m^3 (255 000 million bbl) of oil. This huge inferred resource is contained mainly in the thin Toolebuc Formation which is thought to underlie 400 000 km^2 of inland Australia, extending south from the Gulf of Carpentaria to southern Queensland. Formidable technical and other problems would need to be overcome to enable this resource to be upgraded to 'economic' status.

However, certain oil-shale deposits in Queensland are much thicker, richer, and in geographically favourable locations, and therefore offer more potential for development in the forseeable future. The Rundle deposit near Gladstone, with stated resources of 421 million m^3 (2650 million bbl of oil and the Condor deposit near Prosperpine, with resources of 1294 million m^3 (8150 million bbl) of oil, were the subject of comprehensive feasibility studies by Esso Exploration & Production Australia Ltd and the Japan Australia Oil Shale Corporation respectively. An independent audit of identified resources at Yaamba, which was completed during 1983, confirmed an in situ resource of about 420 million m^3 (2640 million bbl) in an area of about 32 km^2.

Australia's demonstrated resources of oil obtainable from oil shale presently stand at 3819 million m^3 (about 24 020 million bbl), but all of this is still classified as subeconomic; most of the demonstrated resources are in Queensland.

Rundle, Julia Creek, Condor, Stuart, Yaamba, Nagoorin (including Nagoorin South), Lowmead, and Duaringa are the most important resource localities.

There are two major options for development of oil shale deposits: (1) mining, followed by surface processing of shale to extract the oil, and (2) in-situ processing. So far, only the first has been used in commercial oil-shale exploitation. Some in-situ processing methods have been investigated but their developers are awaiting more favourable economic circumstances before committing their processes to commercial application.

IRON AND FERROALLOYS

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

Iron and steel

Australia is a major world producer and exporter of iron ore. The main centres are Newman, Tom Price, Paraburdoo and Pannawonica, all in the Hamersley region of Western Australia, with smaller amounts coming from Shay Gap (also in the Hamersley region), Iron Knob and Iron Baron in the Middleback Ranges of South Australia, Cockatoo Island (Yampi Sound, WA) and Savage River in Tasmania. Savage River ore is low grade and is beneficiated and pelletised before export. Pellet plants operated at Dampier and Cape Lambert (WA) for several years but were closed in 1980.

Integrated iron and steel plants are situated at Port Kembla and Newcastle, NSW, and Whyalla, SA. An electric steel plant at Laverton, Vic. with a capacity of about 200 000 t/year, uses scrap as feed. A blast furnace at Kwinana, WA, was closed in 1982.

Domestic iron and steelmaking absorbed 9.4 Mt of iron ore in 1984. The main sources were Newman and Cockatoo Island, WA, and the Middleback Ranges, SA. Newman supplies more than 60% of domestic blast furnace requirements. About 50 000 t of iron ore (mainly magnetite) is imported each year, principally from Canada, for use as a heavy medium in the coal washing industry. About 25 000 t /year of magnetite is produced in Queensland for the same purpose. Iron oxides are mined for cement-making also.

Even in the 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 was maintained for more than twenty years. The embargo was eased in 1960 and subsequent discoveries showed that Australia has one of the most important iron provinces in the world, and a major export trade has been established.

To illustrate the spectacular change in Australia's resources of iron ore it may be noted that in 1959 the official estimate of reserves with mining potential amounted to only 374 Mt. At that time exploratory drilling in several States had raised hopes that intensified search could reveal some worthwhile new deposits. Among the principal prospects at that time were: Savage River in western Tasmania, where airborne magnetic surveys by BMR had shown a belt of intense anomalies extending over a length of several kilometres; 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 Mount Goldsworthy, near Port Hedland, WA, 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, WA, focused attention on an area hardly touched by modern large-scale mineral prospecting. In little more than a year important deposits were reported from such localities as Deepdale, Robe River, Mount Tom Price, and Mount Newman, all lying in this neglected northwestern part of the State. The discoveries included deposits of hematite (iron oxide, Fe_2O_3) and of limonite (a mixture of hydrated iron oxides); early development at Mount Tom Price, Mount Whaleback, Paraburdoo and Mount Goldsworth, and Koolanooka, east of Geraldton, was based on hematite deposits, but limonite deposits at East Deepdale and hematite-goethite (goethite is an hydrated iron oxide, FeO.OH) deposits near Mount Whaleback particularly are now also worked.

Deposits in Western Australia have since been vigorously tested and very large tonnages of high-grade ore have been demonstrated. Though the full extent is not yet known, BMR assesses economic resources in the Hamersley Iron Province alone at around 20 245 Mt within total economic resources for Australia of 20 716 Mt. In other words, since 1959, Australia's known resources have increased some 55-fold at least and any anxiety for the adequacy of domestic supplies has been removed.

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 than is presently realised. Major expansion projects by the Mount Newman Joint Venture and by Hamersely Iron Pty Ltd, designed to enable low-grade ore to be upgraded, were completed in mid-1979. Robe River also completed an expansion program during 1979 to substantially life production and has extended mining to East Deepdale.

When the export policy was altered in 1960, the change was expected to lead to an increase in prospecting with reasonable chances of providing new reserves. The result exceeded the most optimistic expectations, and led to a situation in which the development of an export trade in ore, which plays an increasing part in the national balance of payments, became the paramount consideration. The first small-scale export of ore, from a small deposit at Koolanooka Hills, began in March 1966 from Geraldton; and after extraordinarily vigorous construction schedules, large-scale export of ore, from new ports at Dampier and Port Hedland in the latter part of that year.

Depressed demand and surplus steel production capacity since the mid-1970s has caused a major restructuring of the world steel industry in the early 1980s. The Australian steel industry has also been forced to adjust to lower production levels and details of a plan aimed at restoring the industry's competitive position internationally were announced by the government in 1983. The plan covers all three primary steelmaking centres, at Newcastle, Port Kembla and Whyalla, and involves capital investment of up to $800 million over four years. Financial assistance is to be provided by the government as bounty payments on domestic sales of particular high alloy and flat steel products at a rate of up to $70 million/year for five years from 1984.

Under the 1983 Steel Industry Plan a series of investment projects totalling more than $525 million were announced in 1984 and early 1985. Major projects at Port Kembla include a second continuous slab caster (cost $146 million), improvements to the hot strip mill ($99 million) reline of No 4 blast furnace ($43.9 million), plate mill improvements ($37.6 million) and new coke ovens battery ($96 million). A continuous bloom caster at Newcastle is to be installed at a cost of $90 million. By 31 May 1985 authorised capital expenditure under the Steel Industry Plan had already exceeded the originally agreed $800 million and stood at more than $860 million.

Manganese (Mn)

Manganese is one of the key metals in the manufacture of steel, its chief use being as a de-oxidiser and de-sulphuriser in the plant process; adequate supplies of its ores (principally pyrolusite, MnO_2) are essential for the long-range security of the steel industry. Current usage requires about 9.5 kg of manganese dioxide for every tonne of steel produced. It is also a hardening consitituent in many grades of steel, and high-quality manganese dioxide is used in the manufacture of dry-cell batteries. In 1984, 312 000 t of manganese ore was required by our industries.

Although Australia's known resources of manganese were for many years small, its self sufficiency in this mineral is now more established. Until the late 1940's the steel industry drew upon deposits in Queensland, New South Wales and South Australia; subsequently Western Australia became the main source of supply.

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 change was designed to encourage exploration, and resulted in a burst of prospecting activity in northwestern Western Australia, during which many new small deposits were discovered amounting, in all, to several million tonnes. In 1960 a discovery of much greater importance was made by BMR officers at Groote Eylandt, in the Gulf of Carpentaria, where BHP has 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, Australia has no production of battery-grade ore and continues to import this at the rate of about 1 000 t/year. In addition, electrolytic manganese dioxide is imported from Japan and USA (1517 t in 1984) for battery manufacture. The possibility of producing battery grade ore at Groote Eylandt is under investigation and research into the production of electrolytic manganese dioxide using Groote Eylandt ore is also underway.

Australia's production of high-carbon ferromanganese now satisifies local demand, but imports of other grades including ferromanganese powder and manganese metal, powder and flakes, totalled 4550 t in 1984. Since the end of production in the Port Hedland district of Western Australia in 1973, Groote Eylandt is now the only large-scale producer of manganese ore.

In recent years a substantial export market has been established for manganese alloys (ferromanganese and silicomanganese) produced at Bell Bay. Exports are estimated at 42 000 t in 1984. Potential for further growth in manganese alloy exports led to the implementation of a 3-year program to expand production capacity at Bell Bay from 135 000 to 190 000 t/year.

Nickel (Ni)

Nickel is used mainly as an alloy in stainless steel (about 47%) and other alloy steel, nickel rich 'superalloys' used in high temperature applications such as gas turbine engines, cast-iron, nickel-copper and copper-nickel alloys, and with chromium or molybdenum and iron in corrosion resistant alloys. The main other users of nickel, chiefly in the form of alloys, are manufacturers of chemicals and allied products and petroleum refiners. Nickel is used in electroplating and, with some of its salts, as catalysts. It is also used in batteries and fuel cells, in carbides and hard facing materials and in ceramics.

The main nickel mineral mined in Australia (and worldwide) is the iron-nickel sulphide pentlandite ($(Fe,Ni)_9S_8$), although most of the world's known resources are contained as oxides and silicates in laterite, a tropical-weathering product of certain rocks. Nickel sulphide ores have the advantage that their extraction is less energy intensive than lateritic ores.

Following the initial discovery, by Western Mining Corporation Ltd (WMC), of sulphide nickel ore at Kambalda in 1966, other companies made important finds and by the end of 1974 fourteen nickel mines were in production. Fluctuating nickel prices and depletion of reserves have since caused some mine closures but several new mines have started up. WMC remains the largest producer of nickel ore from its group of ten mines in the Kambalda field (where proved and probable in situ ore reserves at June 1985 were estimated to be 26 Mt of ore averaging 3.3% Ni) and its 56% share of production from Carnilya Hill (BHP 44%). In 1984 WMC and BHP produced a total of 44 304 t of nickel in concentrate from these mines. Gold is also mined at some of the Kambalda mines.

The Greenvale lateritic mine (Metals Exploration Queensland Pty Ltd/ Freeport Queensland Nickel Inc) in northern Queensland produced 1.71 Mt of ore in 1984. Recoverable ore reserves were 15.1 Mt averaging 1.35% Ni at 31 December 1984. The Yabulu refinery produced 13 076 t of nickel oxide sinter and 1720 t of nickel in nickel-cobalt sulphides.

WMC also mines nickel sulphide ore at Mount Windarra and South Windarra, north of Kalgoorlie. Concentrate from these mines is treated at the WMC smelter, near Kalgoorlie. Agnew Mining Co Pty Ltd (60 percent Seltrust Mining Corp Pty Ltd, 40 percent MIM Holdings) started producing nickel concentrate in mid-1978 from its Agnew mine, 400 km north of Kalgoorlie. In addition to the projects already mentioned, whose output is more than sufficient for Australian requirements, there are several large but low-grade deposits in Western Australia which at the present time are not economically viable. These include lateritic deposits at Wingellina, Ora Banda and Bulong, and sulphide deposits at Mount Keith, Yakabindie, Honeymoon Well, and Sherlock Bay. Several higher-grade but smaller deposits occur at Widgiemooltha and Forrestania (also in Western Australia).

Economic resources of nickel in Australia are about 1.9 Mt. In addition, about 7 Mt of currently subeconomic resources are known to exist.

Production of nickel concentrates began in June 1967 at Kambalda. In 1984, Australia was the third-largest world producer of nickel, behind USSR and Canada. In 1984 virtually all of the nickel mined was processed in Australia, to either metallic nickel, high-grade nickel matte, or sintered nickel oxide. The nickel refinery at Kwinana near Fremantle started production in 1970; the plant has the capacity to produce 30 000 t/year. 25 584 t of refined nickel was produced in 1984. WMC commissioned a nickel smelter near Kalgoorlie in 1972 with a capacity of more than 450 000 t/year of concentrate with potential for substantial further expansion.

Tungsten (W)

Tungsten is used in certain ferroalloys to produce high-speed tungsten steels, and metallic tungsten filaments are used in electric light bulbs. Tungsten carbide approaches diamond in hardness and is used as cutting tips or inserts in cutting tools and in other applications where resistance to extremely abrasive conditions is necessary. Since tungsten became commercially important in about 1900, Australia has been an important producer of its ores - wolframite ($(Fe,Mn)WO_4$) and scheelite ($CaWO_4$) - but the scale of production has varied with widely fluctuating overseas prices. The greater part of production has always been exported. Domestic consumption is small and there should be little difficulty in meeting Australian requirements for ore from known resources.

The principal deposits are in Tasmania and Queensland. Wolframite comes mainly from Mount Carbine in northern Queensland where Queensland Wolfram Pty Ltd also produces minor amounts of scheelite. A major deposit of scheelite has been mined for many years on King Island, Bass Strait, where known reserves are 7.23 Mt, averaging 0.95% tungstic oxide (WO_3).

Natural scheelite concentrate is produced at King Island by both gravity and flotation methods and contains about 2% molybdenum (Mo) in powellite, which is physically inseparable from the scheelite. Its presence in the coarse gravity concentrate is not regarded as a disdadvantage because of the uses of this particular product. However, its presence in the fine flotation concentrate imposes limitations on the marketing of this material, and attracts a price penalty. To overcome this problem, the company has constructed an artificial scheelite plant which chemically treats the fine concentrate, producing a high-grade calcium tungstate or "artificial scheelite" and molybdenum trisulphide.

Australian consumption of tungsten concentrates is about 200 t/year; its main use is in the manufacture of tungsten-carbide-tipped tools.

Molybdenum (Mo)

Molybdenum is used in high-strength low-alloy (HSLA) steels for oil and gas pipelines because of the superior resistance of such steels to corrosion. Some steels in which molybdenum is alloyed with chromium and nickel are used where extreme hardness is required. Molybdenum is also used in lubricants, pigments, corrosion inhibitors, flame retardants, and as a catalyst. Before 1920 substantial quantities of molybdenite were produced in Australia, but for many years production has been small. Imports of molybdenum ore and concentrates increased in 1984 from 63 t to 138 t and imports of ferromolybdenum increased to 168 t.

Most of the molybdenite deposits in Australia are pipe-like in form and development to any appreciable depth is costly. One exception is at Yetholme, NSW, where a disseminated contact deposit aggregating some 800 t of molybdenite lies at shallow depth beneath comparatively thin overburden. An extensive disseminated low-grade molybdenite deposit occurs at Mount Pleasant, 30 km southeast of Mudgee, and there is a large tungsten-molybdenite deposit at Mount Mulgine, WA. A uranium-molybdenum deposit is presently being evaluated at Ben Lomond in Queensland. Molybdenite is currently being mined intermittently with tungsten at the Wofram Camp deposit in North Queensland.

Recovery of molybdenum trisulphide as a by-product from treatment of scheelite at King Island began in 1978. This could supply part of Australia's demand in times of emergency, supplemented by imports from US or Chile.

Chromium (Cr)

Chromite ($(Fe,Mg)(Cr,Al,Fe)_2O_4$), the ore which yields the metal chromium, has two uses in the steel industry: as an ingredient in the production of alloy steel (especially stainless steel), and as a chemically inert furnace lining. Its other main use is in the manufacture of chemicals. Australian annual consumption of chromite, all of which is imported, has averaged about 5000 t in recent years. In 1984 imports were mainly from the Philippines. Imports of ferrochromium were mainly from South Africa. Production of chromite at Barnes Hill, Tasmania ceased in 1980 when reserves were depleted.

The largest known Australian deposit of chromite of economic interest is at Coobina, in the Ophthalmia Range, WA. The only recorded production from this location was between 1952 and 1957 when 14 500 t of ore was produced. The chromite is suitable for metallurgical and chemical use; processing facilities are not available domestically at the present time to warrant development of the deposit. 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 ferrochromium were produced at Newcastle until the closure of the plant at the end of 1974, it is all now imported. In time of emergency Australia could almost certainly revive its domestic ore production to meet local demand.

Vanadium (V)

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.

Substantial resources of vanadium have been recognised in Australia in recent years and several vanadium-bearing deposits have been investigated and evaluated. Agnew Clough Ltd commissioned a vanadium pentoxide extraction plant at Wundowie in June 1980. The plant had a capacity to produce 1620 t/year of vanadium pentoxide flake (98% V_2O_5) from ore mined at a rate of 200 000 t/year from the nearby Coates deposit. Mechanical problems, rising costs and lower prices caused production to be suspended in late 1981.

Australian imports are not recorded as a separate item in overseas trade statistics because only small quantities are involved. Consumption, principally in the steel industry, is estimated at 90-100 t/year.

The possibility of economic development of vanadiferous titaniferous magnetite at Barrambie, 470 km east-northeast of Geraldton, WA, is under investigation. Oil shale deposits at Julia Creek in northwestern Queensland also have potential to produce large quantities of byproduct vanadium. In addition, up to 1000 t/year of vanadium pentoxide could also be produced as by-product from any uranium mining at Yeelirrie in Western Australia.

Overseas sources of supply are mainly USA, South Africa, Finland, and Southwest Africa.

BASE METALS

Copper (Cu)

The first recorded production of copper was in the Kapunda field, SA, in 1842 and at Burra in 1846. In these early years, Australia was one of the world's leading producers, but during the first half of this century known deposits were gradually depleted so that it appeared that Australia would soon become largely dependent upon imports. However, this possibility was dispelled by the confirmation of large resources of copper ore, first discovered in 1931, adjacent to the lead-zinc lodes at Mount Isa. Since then other deposits have been found in other parts of the continent.

Important discoveries of copper mineralisation have been made in recent years in South Australia, Victoria, New South Wales and Western Australia. Exploration is proceeding at these and other prospects, and Australia can be expected to continue to provide not only for its own needs, but for a substantial export trade as well.

The full potential of the Mount Isa deposits was not realised until the early 1950s, although copper was mined for emergency purposes from some minor lodes during world War 2. After the discovery by drilling of high-grade copper lodes, a major new operation got under way in 1953 and output has since grown steadily. The Mount Isa mine is now the most important source of copper in Australia; of the 6 Mt of copper produced in Australia since 1884, most has come from it.

Australian mine production increased also because of expanded output from Mount Lyell and the commissioning of several new mines in the late 1960s and during the 1970s, and is much more than Australian consumption.

Mount Isa produced about 68% of total Australian production in 1984 and has reserves sufficient to support a high rate of production for over 25 years. Other important centres are Mount Lyell, Tas; Cobar, NSW; Woodlawn, NSW; and Tennant Creek, NT. Mining at Mount Gunson is expected to end during early 1986, and production from the Teutonic Bore copper-zinc mine in Western Australia, which commenced in mid-1981, closed in late 1985 because of depleted reserves. Copper is an important byproduct of lead-zinc mining at Broken Hill and nickel mining in Western Australia. Western Mining Corporation Holdings Limited and BP Australia Ltd are to begin development of the Olympic Dam deposit at Roxby Downs, SA. The project will cost around $550-$600 million and produce, in a staged development, 55 000 t of copper, 2000 t of uranium oxide and up to 50 000 ounces of gold each year. Gold production will begin in 1987 and the copper-uranium production is scheduled to begin in 1988. WMC announced in November 1983 that work had established within the mineralised area a probable 450 Mt of material averaging 2.5% copper, 0.8 kg/t U_3O_8, 0.6 g/t gold and 6 g/t silver.

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Other potentially important copper deposits include the Nifty prospect in the Throssell Ranges, about 200 km ESE of Marble Bar, WA, the Scuddles copper-zinc deposit at the Golden Grove prospect near Yalgoo, WA, and the Goonumbla porphyry copper-gold deposits near Parkes.

Australia has two copper refineries - at Port Kembla and at Townsville. The refinery at Townsville (operated by Copper Refineries Pty Ltd, a wholly owned subsidiary of MIM Holdings Ltd), with an annual capacity of around 160 000 t, is by far the larger. It was commissioned in 1959 and refines the whole of the Mount Isa output. Refined copper production is about double Australian consumption. In 1984, 79% of the copper in copper concentrates produced in Australia was processed in Australia to blister or refined metal. The Tennant Creek flash smelter, re-opened by Peko-Wallsend in 1980, was closed down again in October 1981 because of continuing technical and economic problems. The Mount Morgan smelter closed down in July 1984.

Copper is widely used in the building, electrical and electronic and transport industries. Australian production is more than sufficient to meet demand, and there is a well-established fabricating industry. Resources are sufficient for many years.

Lead (Pb)

Lead and zince are usually discussed together because nearly all Australia's production is obtained from orebodies containing the sulphides of both metals (generally galena (PbS) and sphalerite ((Zn,Fe)S)); the lead and zinc are separated by crushing and flotation. Galena also almost always contains silver; it is the most important ore of lead and one of the most important sources of silver.

Australian metal mining began with silver-lead in South Australia in 1841. Since the discovery, in 1883, and development of the Broken Hill lead-zinc-silver orebody, perhaps the richest in the world, Australia has been a major producer of lead and zinc ores and, in the years following 1923, its position was reinforced by the discovery and exploitation of the Mount Isa deposit. Australia has been amongst the world's leading producers of lead for many years and in 1984 it ranked as the second-largest producer in the world behind USSR. Australia's known resources are sufficient to sustain exports for several decades.

The Broken Hill mines and Mount Isa each produce over a third of the lead mined in Australia. Other important sources are the Elura, Woodlawn and Cobar mines in NSW, and the Rosebery-Hercules and Que River mines in Tasmania.

Australia's economic demonstrated resources of lead and zinc constitute about 10% of the world's economic demonstrated resources. Nearly all are in lead and zinc sulphide deposits and the bulk are contained in the Mount Isa, Broken Hill and Cobar regions.

Australia also has substantial resources in the inferred and subeconomic categories that may be reclassified into the economic demonstrated category with some upturn in price levels and couped with cost-reducing advances in technology. A number of prospects are at present the subject of intensive exploration and development. These include Hilton and Hilton North, Lady Loretta and Thalanga in Qld; Scuddles/Golden Grove and Blendevale in WA; and Hellyer in Tas.

Most of Australia's lead concentrates are smelted in Australia, at smelters at Mount Isa, Qld, and Cockle Creek, NSW, which produce lead bullion which is mostly exported, and a smelter and refinery at Port Pirie, SA, which produced 203 366 t of refined lead of which 5400 t was from secondary sources). Output of refined lead from other secondary producers totalled 16 100 t. Domestic consumption increased slightly to 58 800 t.

Lead acid batteries continue to be the most important lead market and account for 45-50% of all lead consumed. Growth in the domestic and world lead markets appears to be closely linked with future developments in the automotive industry, which is the largest single consumer of batteries. The industry is under pressure to manufacture smaller and lighter vehicles which in turn may result in a reduced demand for lead. However, expansion in other applications, including off-road vehicles and standby power plants, will help to offset any decrease. In addition, the future possible introduction of battery-powered electric vehicles could result in a substantial increase in demand.

The implementation of increasingly stringent regulations controlling vehicle exhaust emissions in most countries has resulted in a decrease in consumption of lead (as tetra-ethyl lead) in petrol. It now appears inevitable that the amount of lead so consumed will have fallen considerably by the late 1980s and this end-use, which presently ranks second to batteries, may well disappear altogether by the 1990s. There appears to be little fluctuation in demand for most other uses of lead.

Zinc (Zn)

For a number of years Australia has ranked third behind Canada and USSR as the world's leading producers of zinc ores. The main sources are Mount Isa and the Broken Hill mines; zinc is mined also at Elura, Woodlawn and Cobar, NSW, Rosebery-Hercules and Que River, Tas., Beltana, SA, and Teutonic Bore, WA. The zinc occurs with lead at all these mines except Teutonic Bore, which has zinc-copper ore and Beltana, which is a relatively small zinc silicate deposit.

There are three zinc refineries in Australia - a large electrolytic plant (capacity 210 000 t/year) at Risdon, Tas, based on hydroelectric power; an Imperial Smelting Process plant (capacity 75 000 t/year) at Cockle Creek, NSW; and at Port Pirie, SA, an electrolytic refinery (capacity 45 000 t/year), which recovers zinc from accumulated lead smelter slag dumps as well as granulated smelter slag from current operations. About half of Australia's total zinc concentrates (representing all of Tasmania's output, the bulk of Woodlawn's and Cobar's production, and some of Broken Hill's and Mount Isa's output) is treated at these plants. The remaining concentrates are exported. In addition to production of primary refined zinc about 4500 t is refined from secondary sources each year. Domestic consumption in 1984 declined to 77 000 t of refined zinc.

Growth of the zinc market appears to be closely linked with future developments in galvanising, by far the largest end-use for zinc. In Australia, with continued erosion of the galvanised sheet-steel market by 'zincalume' and the importation of one-sided coated steel products, both of which use less zinc (and the zinc-aluminium surface of 'zincalume' also is claimed to also have twice the life of ordinary galvanised surfaces), prospects for growth appear limited. However, the use of painted zinc coatings on steel surfaces, as well as the introduction of new product lines such as 'galtan' which uses more zinc, may arrest this decline.

Zinc die-castings, the second-largest end use of zinc in Australia, also have met considerable competition from substitute materials. The trend to conservation of energy and weight reduction in automobiles has led to manufacture of thinner, lighter zinc castings and partial substitution by plastics and aluminium, reducing the amount of zinc used in vehicles. The introduction of thin coatings of zinc on car panels and other consumer durables may offset this decline.

Other applications, notably zinc oxide (used as an activator in the rubber industry and as a trace element in fertilisers), zinc dust (consumed mainly in the manufacture of zinc-rich primer paints), and rolled zinc (for dry-cell batteries), appear to be areas where future growth seems assured.

Tin (Sn)

Commercially the most important ore mineral of tin is the oxide, cassiterite (SnO_2). From being a country with a considerable tin export surplus (Australia led the world in tin production for nearly a decade around 1883), Australia became partly dependent on imports about 1947. The revival of several old mining centres radically changed this position and Australia became a net exporter of tin again in 1966.

Production of tin in concentrates has been restricted since 1982 because of export quotas imposed by the International Tin Council on its producer members. World production has exceeded consumption for several years, and the quotas were imposed in an effort to bring the two into balance. Nevertheless over three-quarters of total Australian mine production is exported. Production of primary refined tin is only about half the capacity of the two refineries. One refinery in Sydney can more than meet Australia's requirements of refined tin. An electric smelter at Greenbushes, WA, produces a tin suitable mainly for alloys because of its antimony content. Estimated annual consumption of primary refined tin is about 2 600 t. Tin alloys have many uses - soft solder (tin and lead, used mainly in electronics), bronze, bearing metal, die-casting, and pewter. Tin salts are used in ceramic enamels, plastics, fungicides, and pesticides.

Tinplate, produced at Port Kembla, accounts for about two-thirds of the domestic consumption of tin. Tinplate is susceptible to substition by other packaging materials, but has advantages, particularly in food packaging, that have enabled it to retain much of its share of this sector at least.

The major producers, at Rension Bell and Luina in northwest Tasmania, Ardlethan in central western New South Wales, and Greenbushes in Western Australia, are all lode mines. The major alluvial producer is inland from Cairns in north Queensland. Traditional treatment methods are less suitable for ores in which the cassiterite is very fine grained, especially if other metal sulphide minerals are also common in the ore. This is a problem with some Australian deposits. A process known as matte fuming gives promise that such ores can be economically treated, but has not yet been commercially applied.

Development of several deposits has been deferred because of the uncertain world market. Published ore reserves in most mines are sufficient for only a few years, but further exploration could result in reserves being increased. However, the Renison mine contains more than three-quarters of the total Australian economic demonstrated resources, its annual production is more than Australian consumption, and this mine alone has the potential to supply Australia's requirements of tin into the next century.

Some of the greatest tin-producing countries in the world, Malaysia, Thailand, and Indonesia, lie immediately to the north of Australia, but it is very unlikely that Australia would be unable to supply its own needs in any emergency in the forseeable future.

OTHER METALS

Aluminium (Al)

Over the past two decades the production of aluminium and its ore, bauxite (mainly a mixture of hydrous aluminium oxides and aluminium hydroxides) and alumina (Al_2O_3), a partly processed product, has been one of the most rapidly expanding sectors of Australia's mineral industry. Three decades ago Australia appeared to be seriously deficient in bauxite resources. Although exploration during the war years had shown that there were small domestic resources, and the decision was reached to establish an aluminium smelting industry at Bell Bay, Tas., it was nevertheless believed that the industry would, at most times, be dependent upon imported ores with local ores held in reserve.

A series of discoveries was to change this picture completely. The discoveries began in 1949 when BMR found relatively small deposits of bauxite at Marchinbar Island off the coast of Arnhem Land; this was followed by a more substantial discovery on the mainland near Gove. Later, in 1956, very large deposits of bauxite were found at Weipa on Cape York Peninsula by an exploration company; and in 1958 important new sources were recognised at Jarrahdale in the Darling Ranges close to Perth, where the bauxites had previously been regarded as too low-grade for commercial exploitation. In 1965, an announcement was made of the discovery of further large deposits inland from Admiralty Gulf in the Kimberley district of Western Australia, and in 1973 it was announced that extensive, lower-grade deposits lay to the north of these, on Cape Bougainville.

Exploration during the early 1970s south of the Weipa deposits indicated several hundred million tonnes of bauxite at Aurukun. Australia is now a major world exporter of bauxite, alumina and aluminium. Australian resources are now known to be very large, at least 6500 Mt, and the largest of any country in the world except Guinea. Bauxite mining and shipping facilities at Weipa are currently capable of handling over 11 Mt/year. Facilities in the Darling Range have a total mining and treatment capacity of around 20 Mt/year, while those at Gove, NT can handle 5 Mt/year.

Developments in the field of processing have also been rapid. From 1963, when Alcoa of Australia Ltd commissioned its Kwinana, WA, alumina refinery (present capacity 1.4 Mt/year of alumina), other refineries were commissioned by: Queensland Alumina Ltd at Gladstone, Qld, in 1967 (capacity now 2.7 Mt/year) by Nabalco Pty Ltd at Gove, NT, in 1972 (present capacity 1.2 Mt/year); by Alcoa again, at Pinjarra, WA in 1972 (present capacity 2.4 Mt/year) and at Wagerup, WA, in 1984 (initial capacity 0.5 Mt/year); and by Worsley Alumina Pty Ltd (a partnership of Reynolds, Shell, Dampier, and Kobe) at Worsley WA in 1984 (present capacity 1 Mt/year of alumina).

Total aluminium smelting capacity of Australia's four smelters is presently 858 000 t/year of metal and new construction presently being undertaken is expected to increase this to 1 000 000 t/year by 1986. Australia's smelting capacity is located at Tomago, NSW (Gove Aluminium Ltd/Pechiney Ugine Kuhlmann - 220 000 t/year) Kurri Kurri, NSW (Alcan Australia Ltd - 150 000 t/year), Point Henry, Vic

(Alcoa - 166 000 t/year), Bell Bay, Tas., (Comalco - 117 000 t/year), and Boyne Island, near Gladstone (Comalco - 206 000 t/year). Alcoa recommenced work on its new Portland, Victoria, smelter (planned capacity of the two-potline Stage I, 300 000 t/year). The first potline is expected to be completed by November 1986 and the second by July 1988.

Titanium (Ti)

Australia's resources of the titanium minerals, rutile (TiO_2) and ilmenite ($FeTiO_3$), are adequate; economic resources are put at about 8 Mt of rutile and 40 Mt of ilmenite, although almost half of the resources of rutile on the east coast are currently unavailable for mining because of environmental considerations.

In 1984 Australia supplied about 50% of the world's output of rutile concentrates and about 25% of the world's ilmenite concentrates.

The original uses of rutile were for the manufacture of welding rods and the production of titanium metal; since the early 1960s, by virtue of the choloride method of processing, rutile has been used in the manufacture of pigment for high-gloss white paint, an outlet which now accounts for about 70% of total rutile consumption. The use of ilmenite is virtually confined to pigment manufacture. However, the commercial application of processes by which ilmenite is upgraded to approach rutile in TiO_2 content (beneficiated ilmenite or synthetic rutile) provides a feed for either metal or pigment via the chloride process; beneficiated ilmenite now complements and competes with supplies of natural rutile.

The principal Australian source of rutile is sands on and adjacent to the beaches of its eastern coast. The discovery in 1971 of old shoreline deposits of rutile, zircon, and ilmenite near Eneabba, 270 km north of Perth, constituted a major additional supply of rutile. Commercial production of rutile from this source began in 1975 and installed capacity for rutile production in the area is now about 150 000 t/year. In 1984, production from Western Australia accounted for about 40% of total Australian 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 mid-Queensland coast tends to have a more acceptable chromium content and eventually could provide a suitable base for the production of synthetic rutile. The main operators on the east coast are Consolidated Rutile Ltd on North Stradbroke Island, Qld, Mineral Deposits Ltd at Stockton and Hawks Nest, NSW, and Rutile & Zircon Mines (Newcastle) Ltd at Tomago, NSW.

The ilmenite industry has been built up mainly along the south-western coast of Western Australia. The quality of the ilmenite from this source is most satisfactory for the manufacture of titanium white and, as ilmenite is the main heavy-mineral constituent of the sands, its recovery forms the basis of the industry, together with the production of zircon, rutile, and monazite. In mid-1971 Western Titanium Ltd, now a wholly-owned subsidiary of Associated Minerals Consolidated Ltd, commissioned a commercial beneficiation plant at Capel, WA, and an annual production rate of 45 000 t of beneficiated ilmenite was achieved. The plant is now based mainly on ilmenite from the company's operation at Eneabba, supplemented with secondary ilmenite produced at Capel. However it was closed temporarily in 1983. A semi-commercial plant with an annual capacity of about 15 000 t/year of synthetic rutile, closed down in 1975, was reactivated at the end of 1979. Both rutile and anatase pigments are produced in Australia; both pigments are produced at Bunbury, WA, but only rutile pigment is produced at Burnie, Tas.

Both plants are based on the sulphate process and use ilmenite concentrates produced from the Capel deposits. Australian production capacity for TiO_2 pigments is 55 000 - 60 000 t/year, about 95% of which was utilised in 1984. Ilmenite concentrates are exported from Bunbury and Geraldton, where substantial bulk loading facilities are available.

Australia could be a major producer of beach-sand minerals, at least to the turn of the century. Current known resources of rutile available for mining could be exhausted in the late 1990's.

Zirconium (Zr)

Australian resources of zircon ($ZrSiO_4$) are considerable and are almost twice those of rutile. Again, however, almost half of east-coast resources 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 area, and as a by-product of ilmenite mining in the southwest corner of Western Australia. Western Australia became the leading State producer of zircon concentrates in late 1976, and in 1984 produced about 70% of domestic output.

The market for zircon, principally required by foundries for moulds, facings, and cores, and for refractories and ceramics, faced oversupply in 1970; 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. When world demand recovered the position of oversupply was quickly reversed. However, a position of potential oversupply again developed in 1975 and the Government re-introduced a minimum price for zircon exports, albeit almost five times as high as that in 1971.

In July 1983, Nilcra Ceramics, a joint venture between CRA Ltd and Oliver J. Nilsen (Aust) Ltd, was established to develop, manufacture and market an advanced ceramic product known as partially stabilised zirconia (PSZ). This material has three times the compression strength of steel but is 20% lighter. At the end of 1985 ICI and CSIRO announced the formation of a joint venture company, Z-Tech Pty Ltd, which will market a wide range of zirconia ceramic powders and zirconium chemicals. ICI Australia is to construct a 2000 t /year high grde zirconia and zirconium chemicals plant at Kwinana, WA. The plant is scheduled to be commissioned in stages from mid-1986.

Thorium (Th) and Cerium (Ce)

The main commercial source of thorium, which has been of interest because of its possible nuclear uses, is the mineral monazite ((Ce,La,Nd,Th) (PO_4,SiO_4), a by-product of beach-sand mining on both the east and west coasts of Australia. Notwithstanding the use of thorium in several US experimental reactors, large-scale nuclear use of this material in fast-breeder reactors is said to be many years off. Although research on the nuclear application of thorium continues, commercial introduction of the thorium-uranium fuel cycle in the high-temperature gas-cooled reactor (HTGR) as an industrial source of high temperature heat is not seen before the 1990s although a commercial thorium-fuelled HTGR of 330 MW capacity is operating (at about 35% capacity) in USA.

The 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 1984 were: petroleum catalysts 65%; metallurgy 20%; glass and ceramics 12%; TV, electronics, nuclear, and miscellaneous 3%. Cerium is also present in the mineral allanite $((Ce,Ca,Y)(Al,Fe)_3(SiO_4)_3(OH))$, large quantities of which occurred in the Mary Kathleen uranium deposit.

High-grade monazite concentrates are recovered from beach sands, mainly in Western Australia (accounting for more than 90% of Australia's production) but also in Queensland and New South Wales. The monazite recovered in the southwest corner of Western Australia is a by-product of ilmenite production, but elsewhere it is a by-product of rutile and zircon production. Small tonnages of xenotime (yttrium phosphate) are also produced as a by-product of ilmenite production in the Capel area of Western Australia. Development of extensive mineral sands deposits commenced at Eneabba, about 270 km north of Perth, in 1975, and the area is now a major world source of monazite.

Australia supplies about 60% of non-Communist world output of monazite concentrates. Before 1969 all sales were to export markets, but an old uranium plant at Port Pirie, purchased from the South Australian government, was commissioned in May 1969 to process monazite. In early 1972 an annual throughput rate of 1300 t of monazite concentrates was achieved at the plant for the production of cerium and lanthanum hydrates, yttrium oxide, thorium sulphate, and tri-sodium phosphate. However, financial and marketing difficulties forced closure of the plant in mid-1972.

In 1984, Allied Eneabba Ltd (now a subsidiary of Renison Goldfields Consolidated Ltd) in conjunction with Asahi Chemical Industries Ltd of Japan commenced studies into the possibility of processing monazite to rare earth oxides at Geraldton, WA.

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

Antimony (Sb)

The main end use of antimony is as the compound antimony trioxide, used extensively in fire retardants. However it is also still used to impart hardness and stiffness to lead alloys e.g. in vehicle batteries, as an ingredient in type metal, Babbitt (a soft alloy of tin, antimony, copper, and lead), Britannia metal (alloy of tin, antimony, and copper), pewter, and in the plastics industry.

Of mine production of antimony in 1984, 500 t was produced as antimony concentrates and 420 t was recovered at Port Pirie from Broken Hill Pb-Zn concentrates. In addition, 130 t of antimony was recovered from scrap. All antimony recovered at Port Pirie is recycled to produced antimonial lead (14 460 t in 1984), much of which is exported.

In early 1977 Quelar Chemicals established a small electrolytic antimony refinery in Brisbane. Production in 1977 was reported to be about 3 t of metal, but the high energy costs involved made it uneconomic and the operation was placed on care-and-maintenance in early 1978.

Antimony ores or concentrates have been produced in Australia since the middle of the last century, but most deposits have been worked out. Recently, the only production has come from mines in the Hillgrove area in northeastern New South Wales.

Australia is self-sufficient in antimonial lead, but requires minor imports of high-purity antimony metal and antimony trioxide.

Beryllium (Be)

Beryllium is a lightweight metal processed mainly from the mineral bertrandite ($Be_4Si_2O_7(OH)_2$) but also from beryl ($Be_3Al_2Si_6O_{18}$), good specimens of which may also be marketed as gemstones (e.g. aquamarine and emerald are varieties of beryl). 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 mine production in 1974 was 9 t of contained BeO; there has been no production since 1974.

Most Australian production has come from open-cuts at the Triple Chance mine near Broken Hill, with some production coming also from Olary, SA, across the border, and from the Goldfields district of Western Australia. In times of emergency, particularly if production costs were not to be the principal consideration, the small scattered deposits already known could most probably produce sufficient for Australia's requirements. Main overseas sources are Brazil and USA.

Lithium (Li)

The main uses of lithium are in the glass, ceramics, and pharmaceutical industries, and in the preparation of greases, welding and brazing fluxes and as an energy saving flux used in aluminium smelting. 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 is quite small; requirements, except for occasional purchases from local production, are met by imports. USA dominates the world production scene, but Canada and Chile are also large producers.

Lithium ores were produced intermittently in Australia between 1905 and 1974. Considerable resources of high-grade lithium have been discovered at Greenbushes, WA, adjacent to the tin-tantalum deposits which also occur there. Greenbushes Tin Ltd has begun marketing high-grade lithium concentrates, producing nearly 10 000 t of lithium concentrate in 1984. Low grade lithium resources have been delineated south of Kalgoorlie and near Ravensthorpe, WA, but no plans for development have been announced.

Tantalum (Ta) and columbium (niobium) (Nb)

Tantalum and columbium are metals that occur together in nature and are used in alloying, in high-temperature corrosion-resistant chemical ware, in tipped cutting tools, and in anodes and grids for electronic equipment. Tantalum is used also in semiconductor devices. Australia is an important producer of the ore (tantalite-columbite) which is produced mainly as a co-product of tin mining at Greenbushes, Moolyella and Wodgina in Western Australia and Bynoe Bay in the Northern Territory. Greenbushes Tin Ltd, the main producer, announced in late 1980 the discovery of a major tantalum resource below its present open-cut. On present indications it would appear to be one of the largest-known tantalite deposits of its kind in the world. The company is developing a new mine to begin production in 1986. In addition to concentrates the company produces tantalum and columbium oxides from concentrates, and tantalum-rich tin smelter slag.

Australian production of concentrates is nearly all exported. Presently, there is no domestic demand but should this ever be generated, such could adequately be met from available resources.

Selenium (Se) and tellurium (Te)

Selenium is used in small quantities in the electronic, chemical, glass and metallurgical industries, but is being replaced in some of its uses by the cheaper materials silicon and germanium. There is some production from tankhouse slimes at the electrolytic copper refinery at Port Kembla and a small quantity of selenium-bearing residue is also produced by Sulphide Corporation at Cockle Creek; statistics of production are not available for publication. Peko-Wallsend Ltd produces concentrates containing gold, bismuth, copper, silver, and selenium at Tennant Creek. No payment is received for selenium in concentrates and it is therefore not recorded as production. Domestic consumption is not large. Leading overseas producers are USA, Canada, and Japan.

No Australian production of tellurium has been recorded since 1964, when output was 1.6 t. The metal was then produced mainly as a by-product of copper and lead refining. Small quantities were also recovered from flue gases and dusts generated from the smelting of copper, lead, and bismuth ores, as well as from the roasting of tellurium-rich gold ores, and from the roasting of some pyrite ores for production of sulphuric acid.

Tellurium is mainly used as an additive to cast iron, to improve its machining properties, and in copper alloy springs to increase their life in electrical apparatus.

Bismuth (Bi)

Post World War II production of bismuth in Australia has come almost entirely from the Northern Territory - initially on a small scale as a by-product of tin and tungsten mining and, since 1967, on a much larger scale as a by-product of copper/gold mining at Tennant Creek, by Peko-Wallsend Ltd. Production statistics have, since 1979, not been available for publication; production in 1978 was 1054 t. Bismuth is used mainly as a constituent of fusible alloys and low-melting-point solders, as well as in the production of various salts for use by 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.

Calcium (Ca) and Magnesium (Mg)

Calcium and magnesium occur in abundance in nature as limestone (essentially $Ca\ CO_3$) and dolomite $(Mg,Ca)CO_3$).

Calcium is a soft metal which, because it corrodes rapidly in air, has little use on its own. However, it has found a use as an alloy with lead, to which it imparts hardness. In more recent years it has also found use in a process which recovers uranium metal from uranium hexafluoride.

Magnesium has been called the lightweight champion of metals, being only two-thirds the weight of aluminium. It is used mainly in alloys, particularly with aluminium, to which it imparts strength, and which are used extensively in the aircraft and allied industries.

Neither metal is presently produced in Australia, although magnesium was smelted from magnesite ($Mg\ CO_3$) in limited amounts at Newcastle during World War II. Elsewhere in the world magnesium is produced mainly from seawater. Australia imports magnesium mainly as unwrought metal.

Mercury (Hg)

Australian resources of mercury are negligible. Until 1945, when Australian mine production ceased, about two-thirds of its total output of 23.6 t had come from various small cinnabar deposits in the Kilkivan area of Queensland. Production resumed in 1967, but solely on a by-product basis - by The Electrolytic Zinc Company of Australiasia at Risdon - from roaster gases produced by the calcining of zinc concentrates. No production has been recorded since 1977; production from 1967 to 1977 totalled 8.6 t.

Mercury is used mainly in batteries and other electrical products, in the electrolytic production of chlorine and caustic soda, in paints, in industrial and control instruments, and various other uses.

Imports of mercury are mainly from China, UK, Italy and Spain. World consumption of mercury has declined in recent years because of continuing environmental restrictions.

Silver (Ag)

The main uses of silver are in photography and in electrical and electronic products. Most of the silver produced in Australia is a by-product of lead mining, but some is also a by-product of zinc, copper, and gold mining. Refined silver is produced mainly by The Broken Hill Associated Smelters at Port Pirie, The Electrolytic Refining & Smelting Company of Australia at Port Kembla, and the Perth Mint (from gold bullion), but also by several small refiners recovering silver from primary and secondary material (Johnson Matthey Ltd, Harringtons Metallurgists and Englehard Industries). Production is more than sufficient to meet domestic requirements. Mine production not recovered at refineries is exported as a component of base metal concentrates or lead and gold bullion.

Indium (In)

Indium is another alloy metal not commonly found in economic deposits, but derived mainly from flue dust at lead and zinc smelters. Australia's consumption is negligible and there is no production. The Baal Gammon copper-silver-tin deposit at Herberton, North Queensland, contains indium but recent feasibility studies indicate there is little likelihood of the deposit being worked at present. Indium can be obtained from Canada, USA, Belgium, West Germany, or Japan.

Cobalt (Co)

Cobalt is a by product of nickel and base metal mining; about half the world's production comes from Zambia and Zaire. In Australia it is a by-product of the nickel industry and also of the production of zinc from Broken Hill concentrate. It has a variety of uses which include high-temperature alloys, high-speed steels, and magnetic materials.

Almost all Australian mine production of cobalt is contained in nickel ores. However, only a small proportion of cobalt in mine products is processed to a form suitable for industrial consumption. The zinc refinery at Risdon, Tas., produced 21 t of cobalt oxide from zinc concentrates in 1984.

Nickel-cobalt sulphide products are produced at the nickel refinery at Kwinana and the Yabulu refinery near Townsville, but these products are exported rather than further refined in Australia. These by-products, if suitably refined, would make Australia self-sufficient in cobalt; at present Australia's relatively small requirement is imported in the form of metal and compounds, mainly from the USA.

Cadmium (Cd)

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

In Australia, cadmium is produced solely as a by-product of lead-zinc-silver mining. Refined cadmium is produced at Risdon and Cockle Creek, and in addition crude cadmium is produced at Port Pirie. Estimated domestic sales in 1984 were about 92 t of refined cadmium and the rest was exported, including cadmium contained in lead-zinc-silver concentrates. Australia is more than self-sufficient in this metal, but USA, Canada, and Japan are alternative sources.

Gold (Au)

For the past four years annual production of gold has increased steadily and projections indicate that output will continue to increase for at least the next five years. Australian gold production reached a peak of 119 000 kg in 1903 but had fallen to about 16 000 kg/year by the mid 1970s as rising costs, coupled with a fixed gold price, made most mines uneconomic. In 1976 almost half the total production was from two mines. The Telfer mine, a large low cost operation, began operation in 1977 in the northwest of Western Australia, increasing Australian production by about a quarter.

Higher prices in 1979 and 1980 sparked renewed interest in gold; exploration activity increased and new mines were established, old mines were rehabilitated and numerous dumps were retreated to recover gold left behind by earlier treatment methods. In 1984 thirteen new mines were commissioned. As a result of these developments production increased in 1984 to 39086 kg.

In Western Australia, Northern Territory and Victoria most of the gold produced is won from gold mines; in the other States nearly all the gold produced is a by-product of the mining and refining of other metals, principally copper, lead and zinc. Gold won from goldmines accounts for about 92% of Australian production; 92% of gold mine production in 1984 came from Western Australia. In terms of total 1984 production however, 81% came from Western Australia, 8% from the Northern Territory, 5% from Tasmania, 4% from Queensland, and 2% from New South Wales with small contributions from Victoria and South Australia.

Australia generally has been a net exporter of refined gold, although there have been periods of net imports, usually for monetary reasons. Imports of gold in recent years have been mostly as unrefined bullion imported for refining. The price of gold appears to have moved into a phase of greater stability than in the past, in a range US$300-400/oz. This has encouraged the exploration and development activity referred to above.

Platinum-group metals

The main uses of the metals of this group (iridium, osmium, palladium, platinum, rhodium, ruthenium) are in chemical ware, in jewellery, in alloys used for electrical purposes, as catalysts, particularly in the petroleum industry, and in the glass industry. The automotive industry has become a major consumer for catalysts to minimise undesirable exhaust emissions.

There was a small erratic Australian production of platinum and osmiridium (a natural alloy of osmium and iridium) 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 from platinum deposits has been recorded since 1968.

Platinum-group metals (mainly palladium and platinum) are contained in nickel concentrate produced at Kambalda, WA; production in 1984 of recoverable palladium in nickel concentrate was 523 kg and of recoverable platinum, 66 kg. Palladium and platinum are recovered at Port Kembla, by ER&S, from scrap and by-product copper sulphide residue from WMC's Kwinana nickel refinery. Production in 1984 was 372 kg of palladium and 14 kg of platinum (virtually all from the treatment of copper sulphide residue). The balance of palladium and platinum mine production is exported in nickel matte.

Import data records only the total weight of platinum group alloys and catalysts.

The pattern of world production is stable, with South Africa, USSR, and Canada together accounting for over 98% of world primary production. As sources of supply, however, Canada and USSR are not as consistent as South Africa, because the quantity of platinum-group metals produced in Canada and USSR is dependent on the quantity of nickel produced, and decreases whenever the nickel industry is depressed. In South Africa, on the other hand, platinum is won from mines where it is the primary product, and copper and nickel are by-products.

Platinum group metals have potential for substantially increased use in chemical, petroleum refining, electronics and jewellery applications. Further growth in the use of palladium and platinum as a catalytic converter in automobile exhaust systems is possible in the medium term and the use of platinum in fuel cell technology for electricity generation has potential for growth in the longer term.

GEMSTONES

Diamonds

Diamonds were mined on a small scale in New South Wales as far back as the 1870s and sporadic production continued until 1961; total production until then was 211 188 carats. In the late 1960s an upsurge of diamond exploration led to the discovery of diamonds at numerous places throughout Australia and over a hundred kimberlitic pipes, the usual host rock for diamonds. Diamonds discovered in alluvial deposits at Smoke Creek, in the Kimberley region, WA, led to the discovery of the nearby kimberlitic pipe AK-1 at Argyle, WA, which has proved to be the richest pipe in the world with a grade about eight times richer in diamonds than the highest grade kimberlite pipe in Southern Africa. However, by world standards the Argyle diamonds have a low gemstone content. Reserves are estimated to be 60 Mt of ore grading at 6.8 ct/t, of which 55 percent are industrial, 45 percent cheap gem and 5 percent gem quality diamonds. Investigation of the diamond occurrences in New South Wales has continued but their source has never been identified.

Commercial mining commenced on the Smoke Creek alluvials in January 1983 and production for 1984 amounted to 5.7 million carats, estimated to be about 9 percent of world production. A decision was made to mine the kimberlitic pipe AK-1 from 1986 onwards; the planned production rate is 25 million carats a year, about one-third the non-communist output of natural diamonds.

Until 1983 Australia was a net importer of diamonds but will in future be an important exporter of industrial and gem diamonds.

Sapphires

Sapphires were first discovered in the New England district, NSW, and production from Queensland started in the 1890s. They occur mainly in Tertiary gravels, economic concentrations being found in the Anakie district, Qld, and in the Inverell-Glen Innes-Glenco region, NSW.

Australia produces 70-80% of the world's uncut sapphires including most of the highly prized golden sapphires and the characteristic ink blue sapphire.

It is difficult to estimate Australia's sapphire resources but the widespread distribution of sapphires in parts of New South Wales and Queensland indicates that resources are adequate to maintain production for many years.

Opal

Opal occurs in a variety of highly weathered rocks in Australia. It is mined in South Australia at Andamooka, Coober Pedy and Mintabie, in New South Wales at Lightning Ridge and on a smaller scale at a number of small localities in a zone between Opalton and Yowah in Qld.

Australia produces over 80 percent of the world's opals and all of the world's black opals. The value of production of opal in 1984 is estimated to be $43 million. Accurate figures of production are not known because of the nature of the industry; estimates are made on the basis of mining activity on the opal fields. Australia's undiscovered resources of opal have not been fully assessed but are assumed to be very large.

Other gemstones

Australia produces rhodonite, nephrite (jade), chrysoprase, garnet, zircon, amethyst and small quantities of other gemstones. A small emerald mine, the Aga Khan, WA, was placed on care and maintenance early in 1983.

INDUSTRIAL MINERALS

Industrial minerals generally comprise the non-metallic, non-fuel minerals. While many industrial minerals, and rocks, are used for the chemical elements they contain (e.g. phosphate rock, salt, and fluorspar), many others are used for their physical properties - for example as fillers in plastics, as extenders in paints, and as abrasives, weighting agents, and absorbents. Thus industrial minerals and rocks are used in a wide range of products as well as a wide range of industrial processes.

Notwithstanding that strict product specifications are an essential consideration, industrial minerals tend to have fairly low unit (per tonne) ex-mine values because they tend to be not scare and because they are generally mined in simple, shallow, low-cost surface operations.

For some commodities (such as construction sand and aggregate) there is little scope for adding value as they can be used virtually unprocessed except perhaps for simple washing, crushing and screening. However, many other industrial mineral commodities require beneficiation (by chemical or physical processes) and other forms of chemical and/or physical modification, such as fine-grinding or micronising, all of which can substantially increase product values.

The low unit values limit the distance over which products can be moved economically to markets. Thus the distribution of mining of limestone, dolomite and some clays reflects economic factors (particularly market proximity and transport costs) as well as geological factors (natural occurrences).

The relatively high cost of transporting lower valued commodities has also tended to restrict export opportunities for many industrial minerals. However, salt and gypsum are notable exceptions primarily because these commodities, in Australia, are produced at or very near to the coast. For the same reason Australia imports a large proportion of its requirements of various industrial minerals (e.g., mica, felspar, fluorspar,) even though deposits of these minerals do occur in Australia but in places too remote from markets to make them competitive with imports.

<u>Abrasives</u>

Australia's resources of natural abrasives are restricted to diamonds, garnet, and flint pebble; it has no economic resources of natural corundum (Al_2O_3) and emery (an impure variety of corundum containing varying amounts of iron oxides). Production of industrial (and gem) quality diamonds by Argyle Diamond Mines Joint Venture (led by CRA) from alluvial material began in January 1983 at a rate of about 2 million carats/year; mining of the AK-1 kimberlite pipe started in 1985; the planned production rate is about 25 million carats/year, comprising about 5% gem quality stone, 45% cheap gem, and the remainder industrial grade stone. Annual production will be worth about US$250 million and account for about one-third of non-Communitst output of natural diamonds. The success of the joint venture has spurred intense exploration activity by other companies, both in the Kimberly region and other parts of Australia.

Zaire is the world's major producer of industrial diamonds, followed by USSR and other African countries.

Corundum and emery have been mined on a small scale in Western Australia but there is now no domestic production, and imports of artificial corundum commonly amount to 4000-5000 t/year. Zimbabwe is the world's leading producer of corundum followed by USSR and South Africa. Turkey is easily the largest producer of emery.

Australian production of garnet is all by Target Minerals NL from Port Gregory, WA, about 70 km north of Geraldton, where large-scale production began about 1983. Some garnet is still imported, mainly from USA.

Soft abrasives such as diatomite and ground felspar are produced in Australia in the quantities required.

Arsenic (As)

Arsenic is mainly recovered as a by-product of copper and gold mining and the principal world producers are France, USSR, Mexico, Sweden, and Peru. Arsenic is generally used in industrial chemicals (wood preservatives and mineral flotation reagents), agricultural chemicals (herbicides and plant desiccants), glass and ceramics, non-ferrous alloys, and other uses (mainly pharmaceuticals).

In 1975, Copper Refineries Pty Ltd at Townsville commenced production of copper arsenite, for wood preservative, at the rate of 100-250 t/year. This was the first recorded production of arsenic on a commercial scale in Australia since 1952. Broken Hill Associated Smelters Pty Ltd produces and stores about 200 t of arsenic annually in calcium arsenite, a residue of lead refining at Port Pirie. To date no satisfactory method has been found for treatment of the residue to recover arsenic in a saleable product. Most arsenic required in Australia is imported. A total of 1225 t of arsenic trioxide was imported in 1981; later statistics are not available for publication.

A considerable amount of arsenic was at one time also obtained as a by-product from gold mining at Wiluna, WA, and a number of other Australian sources are known but these are not economically exploitable under present conditions.

Asbestos

Asbestos is the commercial name for a group of six fibrous minerals. Commercially, the most important variety is chrysotile (white asbestos) because of its fineness, strength, flexibility, and suitability for spinning fibre. Other important varieties are amosite, and crocidolite (blue asbestos). Blue asbestos lacks many of the desirable properties of white asbestos, but is stronger and more resistant to chemical action. No detailed statistics on the use of asbestos are collected in Australia, but consumption is mostly for the manufacture of asbestos cement products.

Australia has some resources of blue asbestos (crocidolite) in the Hamersley Range, WA. Deposits of crocidolite near Wittenoom were worked, mainly for export, until 1966 when production stopped because of rising costs.

Australian production of asbestos decreased markedly in 1983 when Australia's sole producer, Chrysotile Corporation of Australia Pty Ltd (a wholly owned subsidiary of Woodsreef Mines Ltd), at Woodsreef, NSW, 15 km east of Barraba, permanently closed its dry-milling plant because decreasing fibre recovery rates and dust control obligations associated with the plant had increased production costs. The company has, for some years, been studying the commercial viability of a wet-milling process and in 1981 it constructed a 1.5 t/day fibre prototype wet-process mill. Although company reports have indicated that technical and economic aspects of the wet-milling process are very encouraging, by the end of 1985 production had not yet restarted.

Asbestos imports in 1984 were almost all chrysotile and shipments were all from Canada and South Africa. Demonstrated economic resources of fibre-bearing rock at Woodsreef total some 19 Mt (BMR estimates the recoverable fibre content as about 2-3%); an additional 16 Mt of material is classified as inferred.

A small quantity of asbestos has also been produced at Baryulgil, NSW, also by Chrysotile Corporation but production from there stopped in 1979.

Barite($BaSO_4$)

Barite, also known as barytes, is naturally occurring barium sulphate. It is one of the heaviest of the non-metallic minerals and is used extensively as a weighting agent in oil-well drilling muds to control gas pressures.

Australian production is nearly all from South Australia, mainly from the Oraparinna region in the Flinders Ranges but also from Olary and Truro; production comprises both industrial-grade material (which, apart from minor amounts imported from China, meets all of Australia's industrial-grade requirements) as well as drilling-grade material. Production from Western Australia stopped in 1981 when the company put the North Pole mine, 110 km east of Port Hedland, WA, on care-and-maintenance.

Minor occurrences of barite are known in every State of Australia but of all such occurrences only one, at Trunkey Creek, NSW, has in recent years, produced small amounts consistently.

Although about 75% of barite production worldwide (6.2 Mt in 1984) is used in drilling muds, barite has various other industrial applications: it is used in the manufacture of glass as a flux and to impart brilliance and clarity; as an extender in paints and as a filler in rubber and linoleum; for making heavy printing paper and in brake linings, clutch facings, and plastics; and because of its high density, inertness, and ability to absorb X-ray and gamma radiation, it also is used in special concretes in hospitals and nuclear reactors for shielding purposes and in barium "meals" for X-rays. Barite is also used for manufacturing a variety of barium chemicals but Australia has no such industry; requirements are met by imports. About 2 600 t of barium chemicals was imported in 1984. Consumption of barite in Australia in 1984 was estimated by BMR as 19 000 t.

Australia has adequate resources of barite which could be brought to production to meet strategic requirements. However, most are in remote localities, mainly in Western Australia and South Australia, where high transportation costs inhibit commercial development.

Clays (bentonite, fuller's earth, kaolin, and other clays)

The term 'clay' is used in a variety of ways; over its long history as an industrial mineral it has come to acquire different meanings related to mineralogy, particle size, and rock type. In this summary clays are grouped as follows:

i. bentonite and fuller's earth;
ii. kaolin, ball clay, halloysite and refractory clays; and
iii. miscellaneous clay and shale.

Bentonite is composed mainly of the mineral montmorillonite, a hydrous aluminium silicate. Bentonitic material may be broadly categorised as either swelling or non-swelling. Swelling types have a capacity for absorbing water, which causes them to swell; when added to water such bentonites form a gel-like mass. Swelling-type bentonites are sometimes referred to as sodium bentonites or sodium montmorillonites. Non-swelling bentonites swell little more than common clays and most crumble in water. However their swelling capacities may be improved by treatment with sodium carbonate. Bentonite is used in a wide range of end uses but particularly as a bonding agent in moulding sand for foundry use, as a sealant to minimise fluid loss by seepage - as in dams, earthworks and in drilling muds - and in stockfeeds.

Australian production of bentonite is mainly from two quarries in the Miles area of southern Queensland and also from near Scone, NSW.

On the basis of production and imports (nearly all from USA), apparent consumption of bentonite in 1984 was about 56 000 t; exports cannot be separately identified because they are included with other clays in a single item.

The term fuller's earth has become a collective term for clay and fine-grained earthy material characterised mainly by its sorptive properties; the principal constituent clay minerals are attapulgite and sepiolite. The term's origin dates back to antiquity when, by virtue of its ability to remove lanolin and dirt, it was used for cleaning and 'fulling' wool. In the latter part of the last century it was found that some such materials could also be used for decolourising and purifying mineral, vegetable and animal oils. Since then the term 'fuller's earth' has been further broadened to include not only 'naturally-active clays', but also 'activated clays' - clays which have had useful properties imparted by treatment with acid. Together, naturally-active and activated clays are sometimes referred to as bleaching clays.

In Australia, attapulgite is produced only from Lake Nerramyne, WA, about 95 km northeast of Geraldton. Production in 1982 was 14 769 t of solar-dried product; data for subsequent years are not available. The company constructed a pilot acid-activation plant at Geraldton to carry out trials on producing a beneficiated product. Apparent consumption of fuller's earth group clays cannot be determined as neither import nor export statistics can be separately identified.

Kaolin is a clay consisting principally of the mineral kaolinite and differing from other clays in its superior qualities of softness, whiteness, and water dispersion characteristics.

Ball clay is defined by the American Society of Testing and Materials as a secondary clay commonly charactised by the presence of some organic matter, high plasticity, high dry strength, long vitrification range, and a light colour when fired. The principal clay mineral is kaolinite.

Halloysite is a mineral very similar to kaolinite. Clays containing halloysite are, like ball clay, considered as a variety of kaolin.

Generally speaking Australian production statistics of kaolin, ball clay and halloysite are grouped in a single item 'kaolin'. Production of paper-coating grade kaolin is restricted to Pittong, Victoria. Filler and other grades of kaolin are produced mainly at Rowsley and Axedale in Victoria; Gulgong, Home Rule, Mudgee, and Albury in New South Wales; Mount Crawford and Birdwood in South Australia; and Mount Kokeby and Mukinbudin in Western Australia.

Kaolin, ball clay and halloysite have widespread applications as a paper and general purpose filler such as in paints, caulking compounds, adhesives and plastics, and for manufacturing vitreous china sanitary ware, tableware china, electrical porcelain, and floor and wall tiles. On the basis of production and imports (exports cannot be separately identified), apparent consumption of kaolin in 1984 was about 200 000 t.

Refractory clays are used in the manufacture of refractory products such as fire bricks and various other shapes, refractory mortars and mixes, ramming and air gun mixes, monolithic and castable materials, retorts, crucibles and various other products. The principal types of clay included in refractory clay are kaolin, some ball clays, and fire clay. The term 'fire clay' is used for refractory clays which do not burn white. It therefore excludes kaolin and, terminology-wise, overlaps with non-white burning refractory-grade ball clays. Fireclays can also have a wider range of silica and alumina content and therefore also include some shales.

Although specifications for refractory clays vary depending on end-use, the main one is obviously heat resistance. The fusion point of refractory clay (including fire clay) is generally in the range 1490-1835°C. Other very important specifications cover resistance to shrinkage, warping, cracking and abrasion.

The principal centres of production of fire clay in Australia are the industrial districts of Ipswich, Queensland, and Newcastle, Sydney, and Wollongong (all NSW), as well as Marulan, Mudgee, Wingin, and Coorabin in New South Wales; Bacchus Marsh, Axedale, Hallam, Rowsley, and Stawell in Victoria; Mount Crawford, Birdwood and Cromer in South Australia; and Clackline, Byford, and Bullsbrook in Western Australia. Imports of fire clay and 'chamotte' (a calcined semi-processed fire clay) in 1984 totalled 13 408 t and were mainly from South Africa.

The category miscellaneous clay and shale includes a wide variety of clay and other fine-grained rocks which are used in a variety of ways. Most products made from them are fired, and include structural and face bricks, pavers, vitrified pipe, roofing tile, quarry tile and other building products. Large quantities of such materials are also 'bloated' by firing, to form lightweight aggregate, and large quantities are also used in making Portland cement. Applications not requiring firing for a finished product include use as a filler, for packing explosives in blast holes, as impermeable membrances in water storages and for plugging oil and gas wells.

Diatomite

There are many small deposits of diatomite in Australia and small-scale production has been almost continuous since 1896; production is now mainly from Barraba, NSW. Apparent consumption of diatomite in Australia in 1984 was 18 000 t, most of which was imported, mainly from USA.

Diatomite ('diatomaceous earth') is a siliceous rock composed mainly of opaline skeletal remains of aquatic organisms called diatoms. Diatomite is used extensively as a filter medium to clarify and purify liquids in breweries, wineries, sugar refineries, food processing plants, dry cleaning plants, chemical and petroleum plants and swimming pools. Diatomite for this use is nearly all imported; Australian diatomite is generally used mainly as a thermal and acoustic insulator in wallboards, as a thermal insulator in kilns, as a filler in paints, varnishes, synthetic plastics, and rubber, as a mild abrasive in various polishes and as an ingredient in lightweight ceramics.

Felspar

Felspar (known mineralogically as feldspar) is the commercial name for, collectively, the most abundant group of rock-forming minerals. However, rocks consisting almost entirely of felspar, and which would thus be of greatest commercial interest, are rather rare. Felspar is used 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. In recent years consumption has been declining because of substitution by nepheline syenite rock in glass manufacture, and the use of recycled glass. Apparent consumption of felspar and nepheline syenite in Australia in 1984 was 22 000 t.

Fertiliser minerals

In Australia, single superphosphate, despite its higher transport costs per unit of phosphorus (P) compared with double and triple superphosphate, remains the most widely used fertiliser because of Australian soils' widespread need for sulphur (S) as well as phosphorus. Other major elements added to soil as fertiliser are nitrogen (N) and potassium (K). Most of the fertilisers are chemically manufactured from mineral raw materials.

Besides the major nutrients, N, P, and K, some soils also require calcium or magnesium which is generally added as ground gypsum, limestone, or dolomite, but details of consumption are not available. Minute quantities of other elements, notably copper, zinc, manganese and iron, also play an important part in plant nutrition. Such "trace elements" are normally applied mixed with the main fertilisers.

Phosphate rock: Phosphate rock is used almost entirely for manufacturing superphosphate, production of which in 1984, in terms of single-superphosphate equivalent (9.6% P basis), was 2.68 Mt. Consumption of superphosphate in Australia has traditionally been subsidised by the Federal Government; presently the phosphate subsidy is $138/tonne of available P, equivalent to $12/tonne for single superphosphate.

Australian fertiliser manufacturers have been almost entirely dependent on phosphate rock imports; these come mainly from Nauru, Christmas Island and USA.

Very large resources of phosphate rock were discovered in 1966 in northwest Queensland by BH South Ltd; these now belong to Western Mining Corp Holdings Ltd. BH South brought its Duchess deposits to production in 1975 but due to flagging export markets and a reluctance by Australian fertiliser manufacturers to modify existing plant to accommodate a new product, failed to achieve anticipated sales and the operation was put on care-and-maintenance in 1978. Operations were resumed in the latter part of 1981, but the mine was again closed down at the end of 1982.

A small quantity of phosphate rock is produced each year in South Australia; this material, because of its high iron and aluminium content, is not suitable for manufacturing superphosphate and is used locally in horticultural applications.

Before mid-1981 the distribution in Australia and New Zealand of phosphate rock from all sources had been controlled by the British Phosphate Commissioners, an inter-government agency representing the governments of Australia, New Zealand and UK. Similarly, the Christmas Island Phosphate Commission, representative of the Australian and New Zealand governments, controlled mining operations on Christmas

Island. As the result of a government enquiry into the phosphate industry, the main recommendations of which were implemented from 1 July 1981, both the BPC and CIPC were phased out. The BPC's role of distributing rock has been taken over by the fertiliser manufacturers themselves, as the Australian Phosphate Corporation Ltd, while all operations on Christmas Island are now carried out by a wholly Australian government owned company called The Phosphate Mining Company of Christmas Island Ltd.

Australia's identified resources of phosphate rock are substantial: 2045 Mt of near-economic (paramarginal) demonstrated resources (average grade 7.4% P), and 1947 Mt of subeconomic inferred resources.

Potash: Potassium, together with nitrogen, phosphorus, and sulphur, is one of the four main nutrients essential for plant life. Potassium deficiencies in soil are generally rectified by applying potassium chloride or potassium sulphate. Australia has no known deposits of either of these salts and its requirements are met by imports, mainly from Canada and USA.

Potassium also occurs as a constituent of the mineral alunite ($KAl_3(SO_4)_2(OH)_6$), deposits of which occur in various parts of Australia. Although these deposits are not regarded as economic sources of potassium, they were as a wartime measure, exploited as a source of potassic fertiliser. At the end of World War II, the Western Australian Government sponsored attempts to produce commercial-grade potash from an estimated 12 Mt of alunitic red mud in Lake Campion, WA, about 50 km north of Merredin. The deposit was worked to 1949, when operations ceased for economic reasons; the venture produced about 13 000 t of potassic fertiliser from about 175 000 t of alunite. Small amounts of alunite have also been produced from Bulahdelah, NSW; production from here stopped in 1952 after about 71 000 t had been produced in the previous 60 years.

In 1973 Texada Mines Pty Ltd commissioned plant to produce langbeinite ($K_2Mg_2(SO_4)_3$) from the residual brine liquor of its salt (sodium chloride)-producing operation at Lake MacLeod, WA. The project was beset by technical problems, declining export markets and ultimately by flooding. The langbeinite operation was then put on care-and-maintenance, pending further feasibility studies. About 10 000 t of material, produced and stockpiled during progressive commissioning of the plant, was sold overseas in 1976 after BHP bought a controlling interest in the company. The controlling interest of the operation has since passed to Dampier Salt (Operations) Pty Ltd, a subsididary of CRA Ltd, but only sodium chloride is now produced.

Nitrates: Australia has no known deposits of nitrates. However, many important nitrogenous compounds are manufactured in Australia, mainly from indigenous material; minor imports supplement local production. The starting point for manufacturing nitrogenous compounds is ammonia (NH_3), which can be produced from various raw materials including natural gas, refinery gas, (imported) naphtha, and water (all for their hydrogen component), and air(for its nitrogen component). The Broken Hill Pty Co Ltd produces about 65 000 t/year of ammonium sulphate from ammonia recovered from coke-oven gas at the company's steelworks at Newcastle and Port Kembla, NSW and Whyalla, SA. Incitec Ltd (formerly Consolidated Fertilizers Ltd, at Gibson Island, Qld), WMC (at Kwinana, WA), and Eastern Nitrogen Ltd (at Newcastle, NSW) manufacture ammonia from natural gas; Kwinana Nitrogen Co Pty Ltd (at Kwinana, WA) makes ammonia from refinery gas; Queensland Nickel Pty Ltd (at Yabulu, Qld) manufactures ammonia from imported naphtha; and Electrolytic Zinc Co of Australasia Ltd (at Risdon, Tas) synthesises ammonia from nitrogen and hydrogen, obtained respectively from fractional distillation of air and electrolysis of water.

The main nitrogenous fertilisers are ammonia, ammonium sulphate, urea, ammonium phosphate, and ammonium nitrate. Compounds of nitrogen are also used in industry; ammonium nitrate is used in some types of explosives and the ammonia produced by WMC and Queensland Nickel is used in metallurgical processes to recover nickel metal from its ore. Australian production statistics for individual nitrogenous compounds are not available for publication, but BMR, using the latest data available, estimates the N content of nitrogenous fertiliser produced in Australia in 1982-83 as 194 600 t; the nitrogen content of imports of various nitrogenous fertilisers in the same period is estimated by BMR as 82 500 t.

Consumption of nitrogenous fertilisers has increased markedly since 1966 when the Commonwealth Government introduced the Nitrogenous Fertiliser Subsidy Act which provided a benefit of $78.74/t of contained N to consumers of nitrogenous fertiliser; the steady increase of consumption is partly due also to the use of nitrogen in new applications, especially wheat, other cereals, and pasture. The Government reduced the subsidy to $60/t of contained N from 1 January 1977, from 1 January 1979 to $40/tonne of contained N, and from 1 January 1980 to $20/t contained N, at which level it has remained.

Fluorite

The mineral fluorite, also known as fluorspar, is naturally occurring calcium fluoride (CaF_2). There has not been any production of this mineral in Australia since 1974 when a small mine near Walwa, Vic. was closed for economic reasons. Historically, fluorspar production in Australia has been on a small scale; in the previous fifty years only about 50 000 tonnes was mined, mainly from the Chillagoe district in Queensland.

Commercial requirements have determined three grades of fluorspar as follows: acid grade - to contain not less than 98% CaF_2; ceramic grade - to contain not less than 85% CaF_2; and metallurgical grade - to contain not less than 80% CaF_2.

Apparent consumption of fluorspar (all grades) in Australia in 1984 was 26 000 t. The steel industry is the largest consumer of fluorspar and The Broken Hill Pty Co Ltd used about 8 000 t of metallurgical-grade material in 1984, as a metallurgical flux for removing impurities in manufacturing steel. The balance represents mostly acid-grade material used mainly in production of anhydrous hydrofluoric acid (HF). There are two HF plants in Australia, at Newcastle and Sydney, NSW. Hydrofluoric acid is an intermediate stage in the manufacture of fluorocarbons, which are used mainly as propellants in aerosol sprays, as refrigerants, and in urethane foam. The use of fluorocarbons by the aerosol industry declined markedly in 1977 because the continuing controversy about the effect of fluorocarbons on the earth's ozone layer encouraged the use of alternative propellants. Small amounts of HF are also used for pickling stainless steel, in petroleum refining, and by the glass industry. Minor quantities of acid-grade and ceramic-grade fluorspar are also used in aluminium smelting, in glass and fibreglass manufacture, in enamels for coating metal ware, and in coatings for welding-rod electrodes.

As well as importing all the fluorspar it requires, Australia also imports various fluorochemicals of which aluminium fluoride and synthetic cryolite (Na_3AlF_6), both used in aluminium smelting, are the most important. In 1983-84 the total f.o.b. value of imports of fluorochemicals wa $22.2 million. Because fluorospar is the major source of fluorine, resources are measured in tonnes of contained fluorine. Of total Australian identified resources of fluorine of

67 Mt, only 3.3 Mt occurs in fluorite deposits; by far the greatest portion of identified resources is contained in the fluorapatite ($Ca_5(PO_4)_3F$) which is the essential component of Australia's resources of phosphate rock. All known fluorite deposits are classified economically as submarginal and none is likely to be developed in the foreseeable future.

Graphite (C)

Graphite has extensive uses as a lubricant, and is also 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 Australia's resource potential has not been fully investigated. All Australia's requirements are met by imports, which amounted in 1984 to 979 t of natural graphite, mainly from China, Korea, and Sri Lanka, and 2086 t of artificial graphite, mainly from Japan, USA, India, China and UK.

Gypsum ($CaSO_4(2H_2O)$

The formation of gypsum usually requires semi-arid conditions. Although Australian occurrences are widespread, they are still within the region where annual rainfall is less than 500 mm. About 60% of Australian production of gypsum is from South Australia, where the main production centres are Lake MacDonnell and Kangaroo Island. Other important areas of production are Shark Bay, Lake Brown, Lake Seabrook, Lake Cowan, Lake Cowcowing and Lake Hillman in Western Australia, and Cowangie and Nowingi in Victoria; a smaller amount is produced from the Cobar Mining Division in New South Wales.

Roughly half Australian production of gypsum is exported; imports are negligible.

Calcined gypsum, or plaster of paris, is widely used in the building industry for plaster board and related products, and also in the manufacture of special plasters for use in pottery, in orthopaedic and dental applications, and as statuary plaster. Gypsum is also an important ingredient in cement and is often also used as a fertiliser and soil conditioner.

Australia's gypsum resources are very large; demonstrated resources total more than 760 Mt.

Limestone, dolomite, and magnesite

Australian resources of these materials - the carbonates of calcium ($CaCO_3$, limestone), magnesium ($MgCO_3$, magnesite), and calcium and magnesium ($(Mg,Ca) CO_3$, dolomite) - are adequate, particularly for limestone and dolomite.

About 70% of Australian production of limestone is used to manufacture portland cement. Apart from this major use, limestone is also used as a flux in metallurgical smelting processes (about 20% of production), for the production of calcium carbide (used mainly in the production of acetylene gas) and other chemicals, and, after fine-grinding, as an industrial product (sometimes referred to as whiting) used as a filler and extender in paints, plastics, and rubber compounds.

Dolomite is used mainly (about 90%) by the iron and steel industry, as a flux in basic-oxygen furnaces, and in the manufacture of tar-bonded refractory bricks (also for basic-oxygen furnaces). Nearly three-quarters of Australia's production is by BHP at Ardrossan, SA.

Magnesite is consumed mainly after calcining, either as chemically active caustic-calcined magnesite (calcined to 700-1000°C) or as inert, dead-burned magnesite (calcined to 1600-1900°C) which is used as a refractory material. Magnesite too is used mainly by the steel industry as a refractory lining in basic-oxygen furnaces, but also as a refractory lining in other types of furnaces and kilns; lesser amounts are also used in the manufacture of oxychloride cement, insulating materials, in agriculture and in chemicals.

Australian mine production of magnesite is mostly from Myrtle Springs, SA and Young and Fifield, NSW. BMR estimates that consumption of magnesite in Australia in 1984, which is partly met from imports, was 90 000 t; this includes the raw magnesite equivalent of imports of magnesium oxide and manufactured refractory products.

Mica

Mica is used mainly in electronics, and also in heat-resistant windows and as a filler. Although Australia's resources are probably large, production has been minor because cheaper material has generally been available from overseas. A few hundred tonnes is now imported each year, while Commonwealth Mica Pool was operating during and after World War II, a series of small mines in the Harts Range in the Northern Territory met most of Australia's requirement. With the winding up of the Mica Pool in 1960, most mining activity stopped. Presently, production is mainly from Mount Crawford near Williamstown, SA, and Pippingarra, WA. In the event of an emergency, mine production could probably be revived to meet requirements. Alternative sources of supply include Argentina, Brazil, China, India, Malagasy Republic and United States.

Pigments and ochres

The terms as used here denote natural earth pigments such as the iron oxides, stained clays, and slate powder which are used to give colour or body to paints, plaster, cement, linoleum, and rubber. A number of small deposits has been worked over the years and Australia undoubtedly has large resources of the iron oxide variety. In recent years, red and yellow ochres have been mined in the Ulverstone-Penguin area of northwest Tasmania and red ochre has been produced in the Weld Range area of Western Australia. Domestic consumption is small. Some 15 000 t of natural and synthetic iron oxides was imported in 1984.

Quartz crystal and silica (both SiO_2)

Australia is self-sufficient in various forms of silica used in glassmaking, foundry sands, refractory bricks, etc., but there has always been a shortage in Australia of high-quality quartz crystal, the piezo-electric properties of which make it so very useful for stabilising frequencies in radio communications. Quartz crystal is also used in optical instruments. A wide search made by Government agencies during World War II failed to discover any substantial deposits, and an intermittent search by industry in subsequent years 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 - 70 t in 1974. The availability of synthetic quartz crystal has eased pressure on the need to discover natural sources.

Over half a million tonnes of high-grade silica sand is exported each year, mainly to Japan, from deposits near Cape Flattery, north Queensland, and near Perth, WA. Imports of mounted piezo-electric quartz crystals in 1984 were valued at $2.4 million.

Salt & other sodium compounds

Salt (NaCl) production in Australia is all by solar evaporation, mainly of sea water but also of underground brines. Most of Australia's production is from four large operations in Western Australia; this is nearly all exported, most of it to Japan. Australia's own salt requirements are supplied by various smaller operations is situated mainly in South Australia, Victoria, and Queensland.

Australia's salt industry expanded rapidly in the 1960s and early 1970s to meet increased demand for salt from Japan's chemical industry; the expansion was confined to Western Australia where about 4.5 Mt/year of new salt production capacity was commissioned. In the mid-1970s export demand slackened and the industry was plagued by excess capacity. The Australian government then set a minimum f.o.b. price of US$8.13/tonne for salt exports but this control was lifted a year later, in March 1977. World demand and salt prices have since improved. The large export-oriented operations in Western Australia are located at Dampier and Lake MacLeod (Dampier Salt), Port Hedland (Leslie Salt Co), and Shark Bay (Shark Bay Salt Pty Ltd); requirements of Western Australia's local markets are supplied by WA Salt Supply (1977) from Lake Deborah near Koolyanobbing and Western Salt Refinery Pty Ltd from Pink Lake near Esperance.

ICI Australia Limited is the largest of Australia's salt producers producing for Australian markets. The company produces about 500 000-600 000t/ year of salt from Dry Creek, SA, for manufacturing sodium carbonate and sodium hyroxide at its nearby alkali plant at Osborne; ICI also produces about 150 000 t/year of salt from underground brine and sea water at Bajool, Qld, about 30 km south of Rockhampton, which the company uses for manufacturing sodium hydroxide at Botany, NSW, and Yarraville, Vic. Other important salt producers (and the location of their operations) are Cheetham Salt Ltd (Port Phillip Bay, Corio Bay, and Lake Tyrrell, all in Victoria, Price and Lake Bumbunga, SA, and Bajool and Bowen, Qld). The Broken Hill Pty Co. Ltd (Whyalla, SA) , and Waratah Gypsum Pty Ltd (Lake MacDonnell, SA).

Although consumption of salt is more evident in households and in food processing industries, the greater part is used by the chemical industry for producing sodium carbonate (soda ash), and sodium hydroxide and co-product chlorine. Sodium carbonate is used mainly in manufacturing glass but also in many other industrial applications, and sodium hydroxide is used mainly in the Bayer process for processing bauxite to alumina. Despite Australia's position as one of the world's main exporters of crude salt, domestic requirements of salt-derived sodium compounds, particularly sodium hydroxide, are largely met by imports because Australia's capacity to process salt to sodium compounds is limited by its capacity to also consume by-product chlorine. Chlorine is used in a variety of chemicals and in many applications; its more important uses are as a bleaching agent, particularly in the paper industry, and in the petrochemical industry for manufacturing vinyl chloride which is a basic building block of many plastics.

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

Sillimanite and Kyanite (both Al_2SiO_5)

These related minerals are consumed mainly in the manufacture of high-alumina refractory linings used in furnaces. Deposits of sillimanite are known in several parts of Australia; presently the only production is from Mount Crawford, SA. Mineral sands in the Eneabba-Jurien Bay area of Western Australia contain large resources of kyanite. Allied Eneabba Pty Ltd commissioned the first stage of a kyanite separation circuit in its mineral sands operation about mid-1982, and in 1984 produced 1255 t of by-product kyanite concentrate. Australian production of sillimanite peaked at 3500 t in 1963 but has since steadily declined. Imports in 1984, under an item which included kyanite, sillimanite, andalusite, mullite, and dinas earth, totalled 2402 t.

South Africa, USA, France and India are major producers. It is likely that Australia could meet its own requirements in any emergency, as the main consideration of exploitation continues to be the cost of transport. The presence of markets in Japan, particularly for kyanite, continues to encourage some exploration.

Sulphur-bearing materials

Commercial deposits of elemental sulphur ('brimstone') and sulphur-bearing ('sour') natural gas are not known in Australia and in recent years about 70% of demand has been met by imports, mainly from Canada. Four oil companies recover sulphur from the refining of imported crude oil; 13 058 t was recovered in 1984. Although combined capacity of their six recovery plants is about 50 000 t/year of elemental sulphur, actual production depends on the sulphur content of the refinery feedstock. However, Australia has large resources of sulphurous materials such as iron sulphide (pyrite), copper sulphide (chalcopyrite),zinc sulphide (sphalerite), and lead sulphide (galena) and sulphur is recovered at several metal smelters and refineries in Australia.

Sulphur is nearly all consumed in the form of sulphuric acid, and in 1984, 34% of Australian sulphuric acid production of 1.85 Mt was from indigenous material, as by-product acid of metal-smelting operations. The metal smelters at which sulphuric acid is recovered (and the material from which it is recovered) are located at Cockle Creek, NSW (lead and zinc concentrates from Broken Hill, Woodlawn and Cobar, NSW), Port Pirie, SA, (lead concentrate from Broken Hill and Elura), and Risdon, Tas(zinc concentrates from Broken Hill, Elura, NSW, Rosebery and Que River, Tas., and Mount Isa, Qld). Western Mining Corporation Ltd recovers sulphur as ammonium sulphate at the company's nickel refinery at Kwinana, WA. A pyrite-based acid plant, at Burnie, Tasmania, which used by-product pyrite from Mount Lyell and Rosebery in Tasmania, ceased production in 1979, for economic reasons.

The recovery of sulphur as sulphuric acid from sinter gases of indigenous sulphide minerals dates back mainly to the early 1950s 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, the Government announced that bounty payments would not be renewed after June 1965 but, on reconsideration, the Sulphuric Acid Bounty Act was first extended to 1969, and then to 1972, when it lapsed.

Imported sulphur is used mainly for manufacturing sulphuric acid which, together with most of the acid recovered from indigenous materials, is used mainly for manufacturing phosphatic fertilisers, particularly single superphosphate, in metallurgical applications and in general chemicals.

In the chemical industry sulphuric acid is used mainly for manufacturing hydrofluoric acid. As a general chemical itself, the use of sulphuric acid extends to many diverse industries and industrial activities including wool scouring, the production of drugs, explosives, glue, leather, paper, soap, glycerine, and detergents, and in lead-acid batteries. In the mineral industry sulphuric acid is used for processing ilmenite to titanium dioxide and for extracting uranium oxide (yellowcake) from its ore. It is also widely used in metallurgical applications, especially for galvanising, tinplating and other electroplating processes, electrolytic copper and zinc refining, and cleaning metal surfaces for soldering and welding. About 29 700 t/year of elemental sulphur was consumed in 1984 for other-than-acid uses, of which the main ones are in insecticides, fungicides, gunpowder, as a vulcanising agent in rubber, and for manufacturing carbon disulphide.

Talc and pyrophyllite

Although talc and pyrophyllite are chemically different (talc is a hydrous silicate of magnesium whereas pyrophyllite is a hydrous aluminium silicate), the two minerals are often discussed together because they have similar physical properties.

Australian production of talc is mostly from Western Australia by two producers at Three Springs, southeast of Geraldton, and Mount Seabrook, northeast of Meekatharra. Mount Fitton, SA, in the northern Flinders Ranges is also an important centre of production, especially for Australian industry. Lower grade and lesser amounts of talc are also mined in South Australia at Gumeracha and Tweedie Gully. Australia is by far a net exporter of talc.

Talc is a very versatile industrial mineral which, after milling, is used in ceramics, paints, rubber, plastics, insecticides, agricultural dusts and, of course, cosmetics. The average level of Australian consumption of talc is about 33 000 t/year.

Pyrophyllite is used mainly as a refractory. Australian production is restricted to two location - Pambula and Mudgee, both in New South Wales. Exports of pyrophyllite, unlike talc, are normally small.

As well as its use as a contact refractory, pyrophyllite, because of its high fusion point, is also used in vitreous china, crockery, electrical porcelain, sanitary ware, wall and floor tiles, and whiteware ceramics generally. Pyrophyllite can substitute for talc in many applications and, with its high anti-skid property, is also used in road-surfacing aggregate.

Major producers of talc and pyrophyllite are Japan, USA, China, South Korea, USSR, and India.

Vermiculite

This mineral has the ability to expand to many times its original volume when heated to high temperatures. It is used in fire and rot-proof building panels, as an insulator in electrical and heating equipment, in the manufacture of building plaster, and as a light-weight aggregate in concrete. Western Australia is the only State in which vermiculite is produced. Requirements are met mainly by imports (3436 t in 1984), South Africa being the main supplier. USA and South Africa account for over 90% of total western world production.

SUMMARY OF MINERAL RESOURCES AND MINERAL PROCESSING

A broad summary of mineral resources (which are not necessarily economic at present) and capacities for mineral processing in Australia, directed particularly toward the performance of the mineral industry in times of emergency, has been attempted in Table 6. Discussions of the magnitude of resources present problems because no realistic estimate of identified resources in Australia is yet available for many of the minerals concerned. BMR each year prepares and publishes estimates of Australia's identified resources of the major minerals, using information available to it (which is not always complete). In Table 6 identified resources have been classified under general categories based on the expected life of known resources at current rates of production, as follows:

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

In some cases, the uncertainty of reserves is indicated.

The table draws attention to a number of cases where mineral resources are available but where there is no associated capacity to produce the metal or processed material needed by the manufacturing industry.

TABLE 1. AUSTRALIAN MINERAL PRODUCTION: QUANTITY AND EX-MINE VALUE OF MINERALS PRODUCED

		1982(r)		1983(r)		1984	
	Unit of quantity	Quantity	Value ($'000)	Quantity	Value ($'000)	Quantity	Value ($'000)**
Antimony ore and concentrate	t	1 029	1 076	111	72	766	
Antimony in mine products	t	1 146	(b)	538	(b)	920	
Asbestos	t	18 587	8 371	3 909	1 587	--	
Barite	t	28 064	765	11 752	288	19 511	
Bauxite	'000 t	23 625	n.a.	24 372 (a)	n.a.	32 182 (a)	
Bismuth concentrate	t	n.a.	n.a.	n.a.	8 075	n.a.	
Bismuth content	t	n.a.	(b)	n.a.	(b)	n.a.	
Cadmium in mine products	t	2 193	(b)	2 275	(b)	2 366	
Carbon dioxide	--	n.a.	295	n.a.	282	n.a.	
Clays, total value	--	n.a.	n.a.	n.a.	34 458	n.a.	
Bentonite and bentonitic clay	t	29 211	856	30 026	1 200	40 000	
Brick clay and shale	'000 t	8 210	26 838	6 203	18 945 (m)	n.a.	
Fullers earth	t	n.a.	n.a.	n.a.	n.a.	n.a.	
Kaolin and ball clay	t	152 133	7 369	115 526	n.a.	195 000	
Other clay	'000 t	2 221	4 956	3 032	3 947	n.a.	
Coal							
Black(c)	'000 t	119 068	3 277 623	120 482	3 430 206	139 094	
Brown	'000 t	37 821	144 402	34 191	142 808	35 108	
Cobalt in mine products	t	3 132	(b)	2 196	(b)	1 620	
Construction materials	'000 t	134 284	604 999	112 731	589 595	n.a.	
Copper ore and concentrate, etc.	t	903 892	269 209 (j)	1 019 580	325 784 (j)	917 325	
Copper content	t	230 409	(b)	249 991	(b)	227 381	
Copper in mine products	t	245 322	(b)	261 476	(b)	236 040	
Copper-tin concentrate	t	2 673	707	1 768	n.a.	1 322	
Copper content	t	602	(b)	405	(b)	305	
Tin content	t	33	(b)	n.a.	(b)	n.a.	
Corundum	t	--	--	472	39	n.a.	
Diatomite	t	1 561	299	7 921	1 321	6 873	
Dolomite	t	602 271	2 426	585 171	2 658	595 869	
Felspar	t	4 335	139	4 244	55	3 390	
Garnet concentrate	t	3 266	223	2 657	93	3 287	
Gemstones							
Diamonds	'000 carats	--	--	6 200	65 415	5 690	
Opal	--	n.a.	39 079	n.a.	44 833	n.a.	
Sapphire	--	n.a.	23 807	n.a.	20 779	n.a.	
Other	--	n.a.	206	n.a.	481	n.a.	
Gold bullion, etc.(d)	kg	n.a.	274 698	32 400	404 977	37 003	
Gold in mine products	kg	26 961	(b)	30 591	(b)	39 101	
Gold ore	t	n.a.	1 511	n.a.	3 206	n.a.	
Alluvial gold	kg	417	4 998	--	--	n.a.	
Gypsum	t	1 863 719	10 367	1 509 800	9 757	1 615 212 (a)	
Ilmenite concentrate	'000 t	1 149	35 196	893	22 396	1 144	
Iron ore	'000 t	87 694	1 436 674	71 037	1 182 717 (e)	88 847	
Iron oxide	t	84 113	2 170	56 888 (m)	2 311 (m)	40 084 (m)	
Lead ore and concentrate	t	777 914	268 331 (j)	852 087	344 011 (j)(m)	804 353	
Lead content	t	416 538	(b)	439 695	(b)	403 551	
Lead in mine products	t	455 338	(b)	480 626	(b)	440 676	
Leucoxene concentrate	t	19 739	3 737	13 358	2 673	15 884	
Limestone	'000 t	12 698	65 217	10 131	50 669	9 567	

Lithium concentrate	t	--	--	2 492	464	n.a.
Magnesite	t	29 671	2 555	20 539	1 610	50 312
Manganese ore	'000 t	1 127	49 939	1 370	70 608	1 829
Mica	t	2 773	269	266	53	2 194
Mineral pigments	t	--	--	--	--	n.a.
Molybdenite concentrate	t	37	160	30	n.a.	17
Molybdenum content	t	13	(b)	11	n.a.	6
Monazite concentrate	t	9 562	3 888	15 141	6 210	17 032
Nickel ore	t	2 152 145	13 043	1 317 069	9 426	1 256 326
Nickel concentrate	t	464 778	n.a.	487 178	n.a.	501 105
Nickel in mine products	t	87 552	(b)	76 625	(b)	76 889
Peat	t	10 101	875	10 026	n.a.	4 886 (f)
Pebbles for grinding	t	1 169	88	n.a.	n.a.	1 000
Perlite	t	1 148	21	2 856	72	3 708
Petroleum, total value(g)	--	n.a.	5 212 905 (e)	n.a.	6 245 579 (e)	n.a.
Crude oil	'000 m^3	20 652	(k)	24 083	(k)	27 775
Natural gas	'000 000 m^3	11 594	(k)	11 914	(k)	12 600
Natural gas condensate	'000 m^3	1 026	(k)	982	(k)	1 410
Ethane(h)	'000 m^3	n.a.	(k)	172 071	(k)	184 300
Liquefied petroleum gas (LPG)(h)	'000 m^3	2 903	(k)	3 070	(k)	3 392
Phosphate rock	t	211 463	8 073	4 868	36	10 945
Pyrophyllite (incl. chlorite)	t	9 467	356	9 569	395	6 851
Rhodonite, industrial	t	--	--	170	44	n.a.
Rhyolite	t	1 743	97	1 168	64	1 246
Rutile concentrate	t	220 697	57 295	163 374	n.a.	181 481
Salt	'000 t	4 684 (a)	57 826 (a)	5 170	69 423	5 537 (a)
Shell grit	t	106	12	413	20	n.a.
Silica (glass, chemicals, etc.)	'000 t	1 813	17 404	1 928	17 039 (m)	1 264
Sillimanite	t	783	63	121	11	507
Silver in mine products	kg	906 863	(b)	1 032 895 (n)	(b)	970 590 (n)
Sulphur in mine products	t	430 191	(b)	454 637	(b)	387 066
Talc	t	143 325	n.a.	167 009	n.a.	234 427
Tantalite-columbite concentrate	kg	166 022	3 879	117 234	3 672	n.a.
Tin concentrate	t	23 134	142 423	17 749	n.a.	14 609
Tin content	t	12 093	(b)	9 252	(b)	7 681
Tin-wolframite concentrate	t	--	--	141	609	108
Tin content	t	--	--	23	(b)	18
W content	t	--	--	41	(b)	35
Tungsten						
Scheelite concentrate	t	2 786	20 772	2 111	13 229	1 571
W content	t	1 594	(b)	1 216	(b)	965
Wolframite concentrate	t	1 850	13 286	1 418	8 906	1 458
W content	t	1 024	(b)	758	(b)	772
Uranium oxide	t	5 215	392 042	3 786	317 351	5 177
Vermiculite	t	429	7	56	1	423
Xenotime concentrate	t	46	180	24	n.a.	36
Zinc ore and concentrate	t	1 173 904	277 714	1 243 395	226 398 (f)	1 164 287
Zinc content	t	593 874	(b)	627 034	(b)	588 716
Zinc in mine products	t	664 800	(b)	699 032	(b)	658 664
Zircon	t	462 476	45 540	382 005	40 887	454 534
Total value			13 349 137		14 474 143	

** Ex-mine values not available because of incomplete data from most States.
(a) Excludes Victoria.
(b) Included in value of mineral in which contained.

XX Ex-mine values not available because of incomplete data from most States
(a) Excludes Victoria.
(b) Included in value of mineral in which contained.
(c) Raw.
(d) Includes retorted gold, etc.
(f) Excludes WA.
(g) Method of valuation differs from previous years; now on a market basis including excise duties, royalties, and other charges.
(h) Excludes refinery production.
(j) Includes premiums for other recoverable metals.
(k) Value of production included in 'Petroleum, total value'above.
(m) Excludes Tasmania.
(n) Excludes silver in gold bullion for Victoria.

TABLE 2. EXPORTS OF MINERAL PRIMARY PRODUCTS

		1982(r)		1983(r)		1984	
	Unit of quantity	Quantity	Value f.o.b. ($'000)	Quantity	Value f.o.b. ($'000)	Quantity	Value f.o.b. ($'000)
Abrasives, natural	--	n.a.	2 311	n.a.	903	n.a.	1 380
Alumina(b)	'000 t	5 951	1 103 255	6 378	1 184 906	6 905	1 276 389
Aluminium, pig, ingot, etc.	t	156 068	168 253	234 562	332 724	336 126	528 398
Antimony ore and concentrate	t	1 557	1 775	1 695	1 819	3 158	2 837
Asbestos, all types	t	15 578	6 467	4 460	2 025	22	9
Barite and witherite	t	608	97	820	373	1 683	333
Cadmium, ingots, etc.	t	662	1 387	935	1 621	899	2 323
Clay, all types	t	5 336	983	7 918	1 041	16 990	1 683
Coal, black	'000 t	46 695	2 524 973	61 379	3 341 881	76 055	3 910 678
Copper							
ore and concentrate	t	159 980	60 249	248 265	104 970	202 190	86 292
lead dross	t	7 348	4 669	7 354	6 633	5 399	4 078
slags and residues	t	348	237	271	227	762	2 329
matte	t	13 911	6 878	4 963	4 702	3 977	2 983
blister	t	7 213	18 888	8 413	23 481	5 350	11 770
refined	t	45 235	65 351	77 632	134 845	75 452	117 078
powders and flakes		782	1 070	991	1 594	618	1 118
in all concentrate, dross, blister, etc.	t	70 429	(a)	80 212	(a)	70 127	(a)
Total copper content	t	116 446	(a)	158 835	(a)	146 197	(a)
Diamonds							
gem	carats	10 822	9 680	3 015 385	36 541	2 682 585	25 896
industrial	carats	269 526	3 073	1 046 103	10 692	898 480	6 012
Gold							
ore and concentrate	kg	83	43	20	112	11	95
refined, bar, dust, ingot, sheet	kg	9 794	135 801	17 743	269 906	30 461	418 048
in all ore, bullion, concentrate, matte, etc.	kg	3 283	(a)	2 872	(a)	1 071	(a)
Total gold content	kg	13 077	(a)	20 615	(a)	31 532	(a)
Gypsum	t	606 891	8 245	803 146	11 946	732 222	10 556
Ilmenite concentrate	t	879 317	22 284	816 933	23 005	1 172 986	33 859
Iron ore and pellets	'000 t	72 711	1 432 005	74 039	1 573 255	85 480	1 615 188
Iron and steel							
pig iron ingots	t	101 399	7 383	468 621	37 573	70 665	7 351
ferroalloys	t	36 178	13 263	50 747	16 660	46 496	16 299
ingots, blooms	t	217 714	37 935	383 663	72 160	293 622	57 617
Lead							
ore and concentrate	t	91 312	36 635	91 227	45 880	150 687	63 618
slag and residues	t	8 661	1 810	7 756	1 329	9 932	1 722
pig (refined) incl. antimonial	t	194 784	121 429	180 636	107 071	147 309	71 329
bullion(c)	t	166 459	176 266	161 624	229 011	205 216	221 898
in bullion		165 433	(a)	159 390	(a)	201 104	(a)
in all ore, slag, matte, etc.	t	52 439	(a)	69 706	(a)	80 779	(a)
Total lead content	t	412 656	(a)	409 732	(a)	429 192	(a)
Leucoxene	t	14 016	2 904	9 276	1 706	30 959	7 062
Magnesite(d)	t	2 831	930	2 808	820	3 984	1 273
Monazite concentrate	t	15 251	6 161	17 670	7 202	18 124	7 629
Nickel							
metal and alloys	t	n.a.	131 583	n.a.	132 403	n.a.	141 641

matte and speiss(f)	t	n.a.	260 357	n.a.	188 383	n.a.	242 945
Opal	-	n.a.	16 732	n.a.	22 685	n.a.	22 758
Petroleum							
crude oil	m^3	97 378	17 738	151 269	32 063	2 529 393	513 707
liquefied petroleum gas (LPG)	t	1 367 290	327 970	1 452 847	428 448	1 440 979	376 304
Pyritic cinder and sulphur	t	530	118	420	108	318	114
Rutile concentrate	t	199 296	50 876	217 662	53 955	191 507	58 018
Salt							
table	t	1 315	439	1 320	505	1 563	657
other	t	4 142 509	54 798	4 533 854	68 883	4 781 370	74 067
Sapphires	-	n.a.	14 464	n.a.	13 479	n.a.	9 886
Silver							
refined, ingot, bar	kg	234 468	63 082	222 480	96 095	163 620	50 589
in all ore, concentrate, etc.	kg	171 069	(a)	221 581	(a)	194 139	(a)
in lead bullion	kg	432 711	(a)	420 435	(a)	354 334	(a)
Total silver content	kg	838 248	(a)	864 496	(a)	712 093	(a)
Talc (incl. steatite)	t	80 512	5 428	131 914	8 401	163 370	10 810
Tantalum and niobium concentrates	t	183	4 390	229	4 739	241	7 221
Tin							
ore and concentrate	t	14 306	84 431	17 729	112 930	11 855	76 616
ingot	t	678	8 100	494	6 948	471	6 534
slags and residues(g)		n.a.	n.a.	98	356	570	1 351
in all ores, etc.	t	7 114	(a)	6 222	(a)	6 150	(a)
Total tin content	t	7 792	(a)	6 716	(a)	6 621	(a)
Tungsten							
scheelite concentrate	t	3 189	23 564	2 355	12 694	1 419	9 647
wolframite concentrate	t	1 750	11 519	1 532	7 595	1 741	9 606
Uranium oxide	t	5 459	415 047	3 273	296 008	3 308	312 079
Zinc							
ore and concentrate	t	569 054	126 081	767 437	162 422	824 526	208 487
slag and residues	t	5 841	2 545	6 469	3 439	7 369	5 344
slabs	t	231 682	196 508	232 651	220 854	220 953	246 865
dust, powder and flakes	t	6 345	3 812	10 533	5 737	9 945	3 985
in all ore, concentrate, etc.	t	302 034	(a)	402 219	(a)	430 064	(a)
Total zinc content	t	540 060	(a)	645 403	(a)	660 962	(a)
Zircon concentrate	t	405 215	43 064	379 975	44 745	437 770	51 819
Other			158 455		198 340		268 295
Total value			8 003 791		9 710 829		11 224 475

(a) Included in value of mineral in which contained.
(b) Includes aluminium hydroxide.
(c) Includes a substantial proportion of contained silver for which separate details are not available.
(d) Includes magnesium oxide.
(f) Includes sintered nickel oxide and nickel cobalt sulphide.
(g) From 1 July 1983.

TABLE 3. IMPORTS OF MINERAL PRIMARY PRODUCTS

		1982(r)		1983(r)		1984	
	Unit of quantity	Quantity	Value ($'000)	Quantity	Value ($'000)	Quantity	Value ($'000)
Abrasives, natural	t	806	310	670	362	1 034	460
Alumina(a)	t	4 435	2 761	3 824	2 459	4 730	3 025
Aluminium, pig, ingot, etc.	t	13 922	18 221	5 225	8 191	709	1 893
Antimony, metal	t	29	77	26	57	41	126
Asbestos, all types	t	20 853	15 186	10 113	8 776	14 432	12 145
Asphalt, bitumen, and natural pitch	t	585	245	758	159	638	249
Barite and witherite	t	3 227	413	1 166	163	1 282	155
Bentonite	t	32 571	2 067	17 767	1 611	24 419	2 617
Bismuth, metal	t	11	41	7	31	14	130
Chromium ore	t	3 912	384	970	123	7 250	854
Clay, all types(b)	t	35 534	4 805	22 629	3 522	39 678	6 044
Coal, black	t	12 183	963	19 255	2 176	22 064	2 375
Cobalt							
ingot, powders and flakes	t	18	524	27	533	30	706
oxide and hydroxide	t	25	457	28	386	29	453
Copper							
ingot and other refinery shapes	t	1	7	--	27	6	10
blister	t	2 175	8 071	4 430	3 120	1	4
Crude oil, enriched crude oil, etc.	'000 m^3	13 857	2 808 080	8 764	1 780 356	8 431	1 681 075
Cryolite and chiolite	t	145	82	2 859	1 706	3 766	2 111
Diamonds							
gem	carat	75 801	32 588	71 981	31 480	91 506	36 142
industrial	carat	1 024 470	4 910	1 120 405	4 162	1 471 480	5 254
Diatomite	t	11 477	2 634	9 884	2 654	11 115	3 113
Fluorspar	t	20 331	1 693	12 676	1 347	25 885	2 266
Gold bullion (gold content)	kg	2 231	15 396	3 161	27 946	3 527	38 670
Graphite, all types	t	1 429	655	795	546	979	557
Gypsum	t	1 136	336	1 555	381	1 158	333
Iron and steel							
ore	t	90 956	2 425	52 096	1 744	52 101	1 724
ingots, blooms	t	1 451	1 585	802	765	5 920	2 684
ferrochrome, ingots	t	2 521	1 685	5 438	3 286	15 000	9 894
ferromanganese (incl. powder)	t	1 834	1 212	1 318	951	2 989	2 151
ferromolybdenum, ingots	t	175	1 389	115	479	168	1 313
ferrosilicon, ingots	t	10 761	6 222	7 174	4 280	9 461	5 273
ferronickel alloy	t	106	616	807	1 115	864	1 687
ferroalloys n.e.i.	t	1 891	3 044	1 636	2 321	2 055	3 411
Limestone	'000 t	977	4 344	833	4 393	940	5 381
Magnesite	t	11 763	4 374	12 215	4 576	13 437	4 293
Magnesium (incl. powder)	t	2 211	5 080	3 479	8 976	2 698	8 654
Manganese ore, all types	t	451	163	1 004	484	1 298	688
Manganese powders and flakes	t	567	740	1 144	1 679	1 561	2 594
Mercury	kg	35 033	382	40 045	416	34 439	356
Mica	t	474	161	335	165	204	90
Nickel							
pig, ingots, anodes	t	1 307	7 631	306	1 718	1 134	5 888
matte, speiss	t	31	166	51	239	..	9
Phosphate rock	'000 t	1 975	102 676	2 198	113 573	1 606	82 095
Platinum and platinum-group metals	kg	3 831	3 422	1 904	2 940	894	3 308

Potassium fertilisers	t	236 471	23 826	197 245	20 064	259 628	28 158
Salt	t	6 596	562	6 235	656	6 447	730
Silver, unwrought	kg	149	61	8 720	451	1 467	488
Sulphur, elemental	t	459 934	39 038	392 581	32 930	470 795	39 642
Talc	t	253	94	147	68	215	111
Tin, ingot	t	63	850	103	1 535	105	1 614
Other	--	n.a.	10 974	n.a.	29 104	n.a.	52 844
Total value			3 143 628		2 121 182		2 065 847

(a) Includes aluminium hydroxide.
(b) Excludes bentonite. Includes andalusite, mullite, Dinas Earth, sillimanite and kyanite.

TABLE 4. SMELTER AND REFINERY PRODUCTION OF PRINCIPAL METALS

Mineral	Unit of Quantity	1982	1983	1984
Alumina	'000 t	6 631	7 231	8 781
Aluminium (refined)	t	380 796	478 190	757 798
Cadmium (refined)	"	1 010	1 106	1 079
Copper (blister)(a)	"	175 536	173 619	179 162
Copper (refined)	"	160 195	168 533	171 180
Gold (refined)(b) Australian origin	kg	23 292	27 551	33 897
Total	"	25 711	29 646	37 003
Lead, (refined)(c)	t	218 812	196 335	198 847
Lead content of lead bullion for export	"	181 592	182 593	179 491
Pig iron	'000 t	5 956	5 045	5 329
Raw steel (d)	"	6 371	5 625	6 299
Silver (refined)	kg	348 019	287 226	276 050
Tin (refined)	t	3 105	2 913	2 899
Zinc (refined)	"	291 390	298 451	301 940

(a) Total production for refining in Australia and overseas.

(b) Newly-won gold.

(c) Includes lead content of lead alloys from primary sources.

(d) Includes recovery from scrap.

TABLE 5: VALUE OF EXPORTS BY AUSTRALIAN STANDARD INDUSTRIAL CLASSIFICATION ($'m)

ASIC Divisions/Sub-division	1981-82	%	1982-83	%	1983-84	%	1984-85	%
Agriculture, forestry, fishing and hunting								
Agriculture	4016		3491		4505		6333	
Forestry and logging	4		7		5		3	
Fishing and hunting	17		13		12		13	
Total	4038	20.7	3511	15.9	4521	18.2	6348	20.7
Mining								
Metallic	1943		2366		2541		2861	
Coal	2292		3075		3331		4607	
Other (a)	411		458		806		1809	
Total	4646	23.7	5899	26.7	6678	26.9	9277	30.3
Manufacturing								
Food, Beverages and tobacco	3687		3823		3750		3848	
Chemical, petroleum and coal products	903		1558		1666		1669	
Basic metal products	2890		3247		3820		4529	
Other manufactures	2659		2804		3147		3571	
Total	10146	51.8	11432	51.8	12383	50.0	13617	44.4
Other Industries (b)	471	2.4	550	2.5	446	1.8	568	1.9
Non merchandise	281	1.4	668	3.0	753	3.0	830	2.7
Total	19576	100.0	22060	100.0	24781	100.0	30640	100.0

(a) Construction materials, other non-metallic minerals, and oil and gas.
(b) Wholesale and retail trade, business services, waste and scrap n.e.c., secondhand goods.

TABLE 6: MINERALS IN AUSTRALIA: ORIGIN, SUPPLY, PROCESSING, ETC

	Availability			Processing			
	Distribution	Identified resources	Current raw material imports	Level of processing	Distribution	Current imports	Possible disadvantages in emergency
<u>Energy minerals</u>							
Petroleum							
(a) Crude oil	Wide but known economic resources mainly in Bass Strait	Medium	About 20% of requirement -crude and refined products	Full range of refinery products & petrochemicals	Well distributed	Some refinery products, heavy crudes	Major supplies offshore. Import of heavy crudes
(b) Natural gas	Wide, but some with long distances to markets	Large	-	Sales gas.LPG for export and home market. ethylene for petrochemicals	Expanding. LNG export to commence 1989	-	Considerable production offshore
Uranium	Northern Australia, WA, SA	Large	-	U_3O(yellow cake) radioisotopes	Northern Australia, Sydney	Radio-isotop	Reserves spread but current plant only in NT
Coal	All states except NT	Very large	Some high-quality anthracite	Coke, coal gas, char, briquettes	Coke-Qld, NSW, SA,Char-Vic.	Petroleum coke	No chemical plants
Oil shale	Eastern Australia	Very large	-	-	-	-	-
<u>Ferrous</u>							
Iron ore	Well distributed but largest resources in WA	Very large	-	Ores, concentrates, pellets, and sinter to iron, steel and fabrications	Steel - NSW, SA, VIC	Ferroalloys, special steels	-

	Availability			Processing			
	Distribution	Identified resources	Current raw material imports	Level of processing	Distribution	Current imports	Possible disadvantages in emergency
Ferrous(continued)							
Nickel	WA, Qld	Very large	-	Concentrates, matte, metal, oxide, sulphide by-product	WA, Qld	Metal and alloys	Metal available but remote from most industrial centres
Chromium	WA, small NSW, Qld	Large metallurgical and chemical	All requirements	-	-	Ferrochromium	Largely dependent on imports.
Manganese	Groote Eylandt, NT	Large metallurgical	Battery-grade	Concentrates, ferromanganese and silico-manganese sinter and alloys	NT, Tasmania	Some ferro-manganese and metal	Main reserves in NT. No metal capacity.
Tungsten	King Island, Tas., and Qld. Minor-NSW, WA	Adequate	-	Concentrates, artificial scheelite, minor carbide	Carbide-NSW	Tungsten	Small tungsten carbide capacity (but could be increased)
Molybdenum	Minor-NSW, Qld, Tas.,WA	Very small	Bulk of requirements	-	-	Ferromolybdenum concentrates	No domestic capacity of acid and ferromolybdenum
Non-ferrous							
Tin	Well distributed - mainly Tas.	Adequate	-	Concentrates and metal	Metal - Sydney; lower quality metal at Greenbushes	Minor	Major deposits not on mainland. Only one refinery of high-grade tin.
Lead	Well distributed - mainly eastern Australia	Large	-	Concentrates, bullion, and metal	Metal - SA, Bullion NSW, Qld.	-	-

	Availability			Processing			
	Distribution	Identified resources	Current raw material imports	Level of processing	Distribution	Current imports	Possible disadvantages in emergency
Non-ferrous (continued)							
Silver	Well distributed - mainly eastern Australia	Large	-	Metal	SA, NSW, Vic. WA.	-	-
Zinc	Well distributed - mainly eastern Australia	Large	-	Concentrates, metal	Metal - Tas., NSW, SA.	-	-
Copper	Well distributed - mainly eastern Australia	Adequate	Small	Concentrates, blister, metal	Metal - Qld., NSW	-	-
Gold	Well distributed	Adequate	Some unrefined bullion and scrap	Refined bullion	Mostly WA (Perth); also SA, NSW, Qld	-	-
Mineral Sands							
Titanium	E and SW coasts	Adequate	-	Concentrates, upgraded ilmenite, pigment	Pigment - WA, Tas.	Metal and small tonnages of special-type pigment	No metal capacity
Zirconium	E and SW coasts	Adequate	-	Concentrates	-	-	No metal capacity; Zirconia plant scheduled for 1987
Monazite	E and SW coasts	Adequate	-	Concentrates	-	-	

	Availability			Processing			
	Distribution	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, metal	Metal - NSW, Vic., Tas.,	Minor shapes	Major resources Qld. remote from smelters
Magnesium	Well distributed	Adequate	About 60% magnesite	Calcining and dead-burning	-	All metal	No metal capacity
Fertiliser/industrial minerals							
Phosphorus (phosphate rock)	NW Qld, NT	Very large	All requirements	Fertiliser	All States	Some mixed fertilisers	Domestic resources mainly in NW Qld, NT
Potassium	WA	Appear adequate	All requirements	Fertiliser	All States	Some mixed	Deposits remote from factories
Sulphur	(Sulphides) well distributed	Elemental nil, sulphide large	70-80% of requirements	Acid	All States	Small amounts of acid	-
Salt	Well distributed	Unlimited	-	Salt, sodium hydroxide, chlorine, sodium carbonate	NSW, Vic., SA	Some chlorine, 70% caustic soda require-ments.	-
Diamonds	WA	Large		Gem and industrial diamond separation	-	Some gem and industrial diamonds	Only source in NW Australia

	Availability			Processing			
	Distribution	Identified resources	Current raw material imports	Level of processing	Distribution	Current imports	Possible disadvantages in emergency
Fertiliser/industrial minerals (continued)							
Asbestos	NSW, WA	Chrysotile (short fibre) adequate; Crocidolite (long fibre) very small	Small All requirements	Fibre grades	NSW	Fibre grades	Not all grades produced
Fluorspar	WA, Qld	Adequate	All requirements	Hydrofluoric acid	NSW	-	Deposits low grade and in
Minor metals							
Vanadium	WA, Qld (including oil shale and uranium)	Large	-	Vanadium pentoxide (production suspended)	WA	All vanadium & composites	-
Bismuth	Mainly NT	Adequate	-	Bismuth concentrates containing gold & copper	-	All metal	Small metal capacity
Cobalt	Eastern Australia, WA	Adequate (from nickel ores)	-	Oxide and sulphide by-products	Qld, WA, Tas.	Cobalt, cobalt alloys, oxides and hydroxides	No metal or alloy capacity
Mercury	Eastern Australia	Small but uncertain	-	-	Tas.	All requirements	No production - could be commissioned
Mica	Central and Western Australia	Adequate	-	-	-	All grades	No current operation but could be produced

	Availability			Processing			
	Distribution	Identified resources	Current raw Material imports	Level of processing	Distribution	Current imports	Possible disadvantages in emergency
<u>Minor metals (Continued)</u>							
Cadmium	NSW, Tas, Qld	Adequate	-	Metal (by-product)	NSW, SA, Tas.	-	-
Antimony	NSW, Victoria	Adequate	Very small	Metal (by-product) contained in antimonal lead	SA	Metal plus oxides	-
Beryllium	NSW, WA	Small but uncertain	-	-	-	Any metal required	No metal capacity
Tantalum	WA	Large	Bulk of requirements	Upgraded Ta_2O_5	WA	All metal	No metal capacity
Columbium	WA	Large	Bulk of requirements	Upgraded Nb_2O_5	WA	All metal	No metal capacity
Lithium	WA	Large	Bulk of requirements	Concentrates	WA	All requirements	No metal or carbonate capacity