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MINERAL RESOURCES OF AUSTRALIA

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ABSTRACT

The Australian mineral industry in the past three decades has grown into an industrial giant. 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 more than $6 billion and Australia's favourable annual balance in mineral trade is about $4 billion.

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 in the last three decades. 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 five times as great as that of imports. Coal, iron ore, and the products of bauxite mining account for about 70 percent of the value of mineral exports; oil continues to be our most costly mineral import and accounts for about 80 percent 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, mineral fertilisers, diamonds, and ferroalloys) are 'economic' rather than geological deficiencies.

Government has assisted the development of the mineral industry by providing topographic, bathymetric, geological, and geophysical mapping; through bounties, subsidies, and taxation concessions; by export controls; and by stockpiling. As a result of a rich natural mineral endowment, stable Government, wise Government policies, and the enterprise of the private sector the overall picture of the Australian mineral industry is now a most favourable one. However, programs of vigorous exploration must continue, to ensure that future demands for minerals, both domestic and export-oriented, will be met not only from resources now identified but also from future discoveries and their development.

CONTENTS

TABLES

FIGURE

5

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 Mineral Economics Section, the Petroleum Technology Section, and particularly Mr A.G.L. Paine of the Publications and Information Section of the Operations Branch, who edited this Record.

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 population and capital which followed the early mineral discoveries. This flow reached a peak towards the end of the last century, then slackened for almost fifty years; it began again in the last 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 of industrial groups within Australia, given in Table 1, shows the rising impact of the mineral industry on overseas funds as the largest single export earner in recent years. The contribution of mines and quarries in 1978-79, given as 28.5 percent of all exports, is in fact higher, because the industrial classification used in Table 1 allocates some exports by the smelting and refining sections of the industry to 'manufactures'. For example, if the value of alumina is added to mineral exports the contribution rises to 34.0 percent.

However, the mineral industry cannot be seen in perspective without identifying problems as well as achievements. The need for additional reserves of crude oil is urgent; the use of foreign capital in both exploration and development has eroded Australian equity in the industry; restricted domestic markets for processed products, amongst other factors, continue to place restraints on mineral processing; inflation and increase in domestic costs, relative to those overseas, have eroded our competitiveness and discouraged many new developments; and the prosperity of the industry, inevitably based on exports although benefiting from long-term contracts, remains heavily dependent on the Japanese economy, which currently provides markets for 44 percent by value of our mineral exports. Indeed the temporary slowing down of the Australian mineral industry from 1975 to 1978, as a result of lower world metal prices and of checks to the economy of both USA and Japan in particular, serves as a salutary reminder of our vital concern with world economies and of our need to diversify our mineral trade as much as possible.

Reactions from Australian and foreign stock exchanges, the inevitable failure of some ill-equipped small mining companies, and other regrettable but spectacular events following 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 has continued to progress. The value of ex-mine production and of exports continued to rise. The level of exploration funds, in real terms, declined in 1975 and 1976; it rose slightly in 1977 and continued this recovery in 1978 and 1979; a high rate of exploration is important if Australia is to be provided with the additional ore deposits required for continued development of the mineral industry in the 1980s, and is to be able to make proper assessments of its resources.

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

In the twenty years to 1973 both State and Commonwealth Governments encouraged private enterprise from both domestic and foreign sources to carry out detailed prospecting and development aided by governmental contributions through regional mapping and other fundamental scientific work, and by financial assistance in some areas.

7

In recent years, both State and Commonwealth Governments have become more concerned with the details and the timing of mineral development. The end of 1972 brought important changes in minerals policy under a Labor Government, with emphasis on Australian ownership of mineral resources; these changes included the establishment of a Pipeline Authority to purchase and distribute natural gas throughout the continent, restrictions on the inflow of foreign funds and on exploration by foreign companies, and proposals (submitted to the Commonwealth Parliament in late 1973) to strengthen the Australian Industry Development Corporation (AIDC) and to establish a Petroleum & Minerals Authority.

In the event, these changes in policy, which included reduced taxation incentives, brought some confusion and indecision to the mineral industry because new guidelines were not clearly established; this was under way at the end of 1975, when the Labor Government was replaced by a new Liberal/National Country Party administration. The Labor proposals for revision of the AIDC were never passed by the Senate; legislation to establish the PMA was declared invalid by the High Court, although the nucleus of a PMA did invest some $2.9 million in the Australian mineral industry up to late 1975. The new Liberal/NCP Government abolished the PMA and reorganised the Pipeline Authority. However, it adopted guidelines for foreign investment in the Australian mineral industry along the lines of those announced by the previous Labor Government; the guidelines called for 50 percent Australian equity in the development stage and 75 percent in the case of uranium. However, the present Government has increased incentives, largely in the taxation field, and has indicated that its guidelines on the level of Australian equity desired in the development of mining projects will be flexible so that projects of national importance may proceed in cases where available Australian financial support is less than required by the guidelines.

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

On page 69 reference is made to some of the policies followed in recent years with the intention of encouraging development or of conserving national resources. Attached also (Table 2) is a summary of ore reserves and of mineral processing in Australia as an indication of both resources and processing facilities. Overseas trade in minerals and mineral sufficiency are illustrated in a diagram at the end of this paper showing values of imports and exports of minerals in 1979.

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

Mineral statistics given are those for 1979, 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 in the last three decades.

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 incentives and the emergence of markets.

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 that time, Britain was not seeking mineral supplies overseas and did not encourage the young colony to explore for minerals. Moreover, the colony, first established as a penal settlement, was preoccupied in early years in learning how to feed itself, with little interest in mineral deposits; partly for this reason scientific contributions 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 1893 and subsequently of the gold lodes of Kalgoorlie extended profitable mining to the western portion of the continent at a time when the economy in the east badly needed new outlets.

The lean years 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

11

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 increases 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, 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 steelmaking from Lithgow to the coast near Wollongong in 1928, but subsequent trouble in the depression in the early 1930s led to this project being taken over by The Broken Hill Pty Co. Ltd in 1932. In 1919 the Victorian Government passed legislation to establish the brown coal industry in the Latrobe Valley, based on large deposits discovered 30 years earlier.

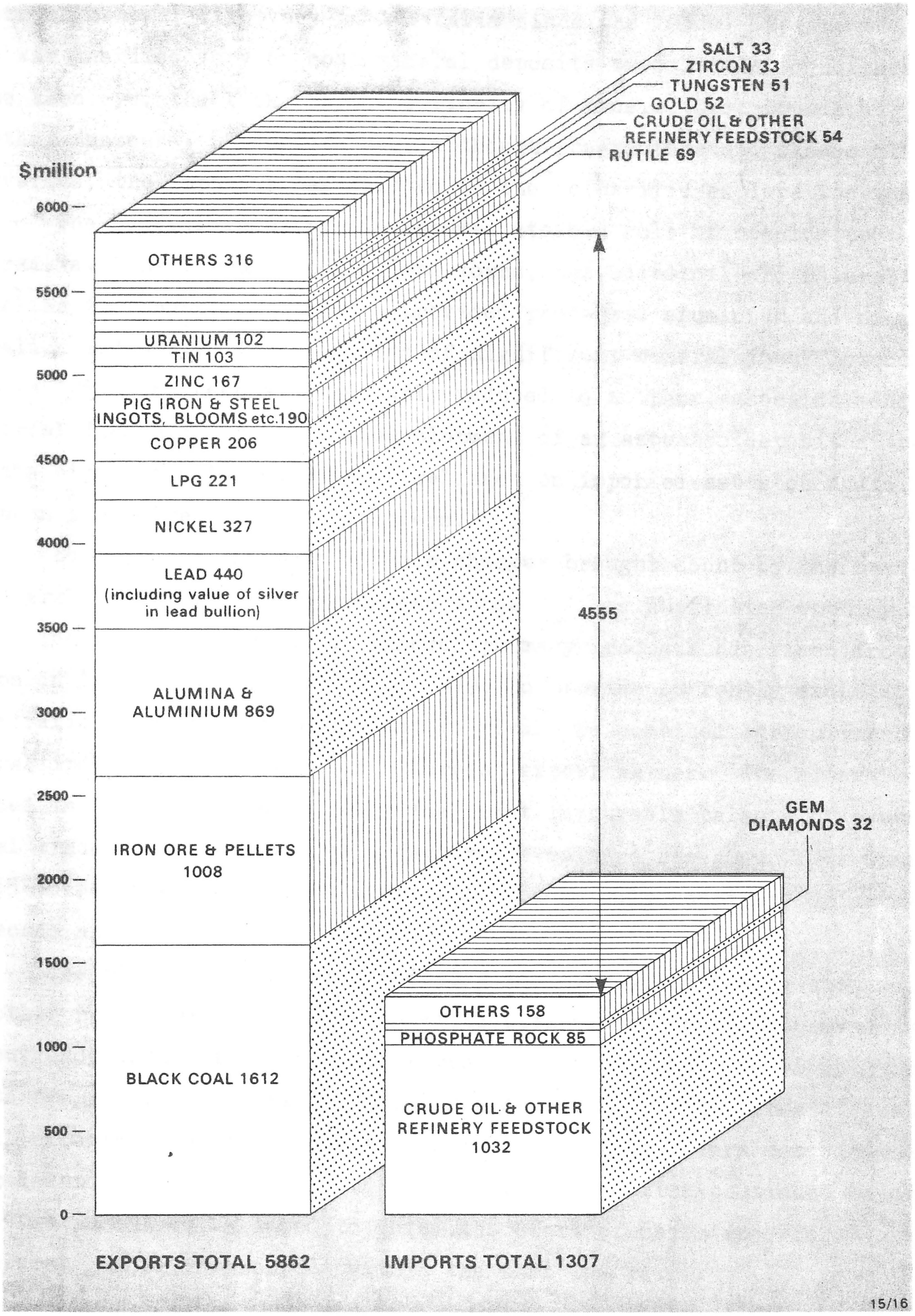
In the late 1930s the mineral industry, although well established, played a minor role in the Australian economy. It had been particularly successful in opening up the country, had provided coal as fuel in all States, had bolstered the economy about the turn of the century, and continued to provide steel, 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 million tonnes, 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.



AUSTRALIAN BALANCE OF TRADE IN MINERAL PRODUCTS, 1979 $ million

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.

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 spectacularly reduced to sulphur, asbestos, and industrial diamonds; recently, development of an asbestos deposit at Barraba, NSW, has significantly reduced our reliance on imported asbestos and diamonds have been discovered in the Kimberleys.

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 $5862 million in 1979, to provide currently about 40 percent of Australia's overseas earnings and to rival 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 $4555 million in 1979 and will undoubtedly continue to increase in the decade ahead.

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 two-thirds of Australian mineral exports, are very large and, combined with long term contracts and rising demand for minerals throughout the world, promise continued major production and export. Added to this, the start of major exports of uranium and 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 population of only 14 million; overseas funds were sought and accepted in terms of risk capital for exploration and investment in mining operations, with inevitable erosion of Australian equity in both petroleum and mining industries. Moreover, since ore reserves are wasting assets, a continued flow of risk capital is required in the future to provide more reserves, particularly of crude oil if Australia's present 70-percent self-sufficiency in oil is to last.

Australia has until recently been shielded to a large extent from the world crude oil crisis by the level and prices of domestic supplies. But likely depletion rates have already emphasised the fact that, considering the lead time involved in discovery and development of petroleum resources, the cost of crude oil imports must rise significantly, and indeed the Government has set the price of oil discovered from 14 September 1975 at world parity. In 1977 it enacted measures to increase the price of oil discovered before 14 September 1975 in stages to 50 percent of import parity in 1981, with a view to achieving full import parity by 1985.

Inflation in Australia has increased the cost of exploration, development, and production, reduced profitability, increased cut-off grades, and discouraged new developments, particularly where real world metal prices, such as those for copper, have not kept pace with inflation. Restraints to mineral development were also increased by changes in taxation schedules and particularly by the repeal of provision for accelerated depreciation in the mineral industry, although changes in 1976 and 1977 have provided more encouragement.

The world economic recession has added to the industry's problems because of the restricted domestic market and consequent 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 - the mining industry has so far taken the brunt of the attack; as a result the mining industry no longer operates with the degree of isolation from the rest of the community that was evident in previous years.

To these problems has been added in more recent years growing concern about the future availability of non-renewable mineral resources and the need for conservation on a world scale. Doubtless these concerns are timely and salutary, although in many cases exaggerated; they are beyond the purpose of this summary, but they provide some of the evidence to suggest that the 1970s in Australia may well have begun the transition of the mineral industry from the boom years into a fourth stage of development in which enthusiastic search and development gives place to consolidation and to more deliberate development, and in which attempts will be made to better relate the potential and problems of the mineral industry to overall community needs.

ENERGY MINERALS

Petroleum*

Australia's main mineral deficiency has long been that of indigenous petroleum, particularly crude oil, the lack of which has compelled us to import significant amounts of crude oil and refined products to meet increasing consumption. In 1979 the value of imports of refinery feedstock and refined products rose to $1032 million (crude oil $535 million) from $929.57 million (crude oil $627 million) in 1978, mainly reflecting the increase in world prices; indigenous crude oil supplied about 70 percent of demand in 1979. An increase of 1.7 percent over the previous year in consumption of marketable petroleum products took place in 1979. Consumption is expected to rise by some 65 million barrels per day (10%) over the next 10 years; the average annual increase in consumption for the five years ended 31 December 1979 was 1.8 percent.

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*Prepared by Petroleum Exploration Branch

17

Since the mid-1950s an Australia-wide search has been going on. In 1965, 156 exploratory wells were drilled in Australia, compared with 14 in 1959; in succeeding years the number ranged from 72 up to 119 in 1970, then fell from 100 in 1972 to only 19 in 1976 and 21 in 1977, but rose to 52 in 1979. Based on exploratory programs announced for 1980 the number of exploratory wells estimated to be drilled is between 63 and 84. By the end of June, 1980, a total of 33 exploration wells had been drilled (7 onshore and 26 offshore). This figure is a considerable improvement on the 17 exploration wells drilled by the same period in 1979 (the level of drilling in the first half of a year is often affected by the 'wet season' which often restricts onshore rig mobilisations in the northern half of Australia).

Part of the reason for the increased tempo of petroleum exploration in Australia in the 1960s undoubtedly derived from the Commonwealth's policy of subsidising private companies' expenditure under a scheme first introduced in 1958, extended to June 1969, and further extended until its termination in June 1974. Under this scheme selected operations were at first reimbursed by 50 percent (later reduced to 30 percent) of the cost. The 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 Queensland and the Kincora and Boxleigh-Silver Springs gas fields now supplying Brisbane with natural gas; the Gidgealpa-Moomba-Big Lake (and the nearby Toolachee) gas 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; and the Dongara field in WA now supplying Perth. Other gas fields still to be developed are Mereenie-Palm Valley in the Northern Territory and fields on the Northwest Shelf off Western Australia where development plans are well advanced and initial work has already started. Gas has also been discovered in the Tern well, 300 km west-southwest of Darwin. Several major discoveries of natural gas on the Northwest Shelf are being appraised and production plans formulated. In September 1975 the incentive to explore was further increased by the introduction of the Governments "new oil" pricing policy with the introduction of world parity price for "new oil" discovered after 14 September 1975. There have been further amendments to this policy since the original announcement.

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 in the Barracouta, Marlin, Mackerel, Tuna, Flounder and Cobia fields and more recently at Fortescue in the same basin. Plans are well advanced for the installation of production platforms at West Kingfish, Cobia and Fortescue. Commercial production of gas began from Barracouta in late 1969 and was followed by oil from Halibut in 1970, Kingfish in 1971, and Mackerel in 1977. The Tuna oil field was brought into production in 1979. At the end of June 1980 development drilling was still in progress on the Mackerel and Tuna platforms and the Snapper platform was being prepared for drilling.

At present, companies hold exploration permits over selected areas in most sedimentary basins. Interest has turned to the offshore localities, in deeper waters such as the Exmouth Plateau off Western Australia. Drilling offshore is much more expensive than drilling on land, but the prospects are considered good. The first offshore rig, Glomar III, a drill ship, was brought to Australia in 1964. 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. Three of these units were drill ships, two were semi-submersible platforms, and one was a jack-up unit. Only two units, 'Ocean Digger' and 'Ocean Endeavour', both Australian-flag units, were in operation by the end of 1976. At the end of 1979 four mobile offshore units were active, three 'Sedco 455', 'Sedco 471', and 'Sedco 472' were idle or between operations and two platform rigs were active on the Mackerel and Tuna platforms. Of the four active offshore units, three were dynamically positioned units drilling in the very deep waters of the Exmouth Plateau where 8 wells have been drilled resulting in only one major gas discovery which because of the water depth (930 m) is non-commercial.

The year 1969 saw the completion of three major natural gas pipelines. The 170-km, (760 mm) (30-inch) pipeline from Longford to Dandenong first delivered gas to Melbourne and its environs in early 1969, and in the December quarter of 1979 was delivering about 11.0 million m^3/day.

Brisbane received its first delivery of natural gas from the Roma area in March 1969 through the 270 mm (10 3/4-inch), 410-km pipeline. Production from this area together with that from the Kincara and Boxleigh-Silver Springs fields in the December quarter of 1979 was being sustained at a daily rate of some 0.8 million m^3/day.

In late 1969, Adelaide received natural gas through the 560 mm (22-inch) 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 late December 1976. The average rate of gas production from the Cooper Basin fields to Adelaide and Sydney at the end of 1979 was 8.78 million m^3/day. Natural gas was delivered to the Perth area from the Dongara field in October 1971, and in the December quarter of 1979 the rate averaged 2.34 million m^3/day.

In 1979, indigenous oil production supplied about 69 to 70 percent of Australia's requirements. However, the crude oils discovered so far are deficient in the heavier distillation fractions required by heavy industry and for road and paving construction; thus, import of crudes rich in these fractions must continue, at about 30 percent of total consumption, until an adequate source is found in Australia. Also, since national consumption on average is increasing at about 1.8 percent/year, further substantial Australian discoveries are essential.

Should we fail to find more petroleum, it will be necessary 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 our oil shale deposits, particularly in Queensland; our very extensive resources of coal may provide an alternative source if economic methods of conversion can be developed to suit them. Research into coal conversion is now active in Australia and abroad (e.g. especially USA and West Germany).

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

Uranium

Australia is not a consumer of uranium, although small quantities of uranium-derived fuels are imported for use in research at the atomic reactor at Lucas Heights near Sydney. Some 15 years ago we completed a brief but important period as a producer of uranium ore and we are now on the threshhold of becoming a much more important producer. The national search for deposits began in 1944 and bore its first fruit in the discovery of Rum Jungle in 1949 and of Mary

Kathleen in 1954. Some small deposits were known in South Australia as early as 1906, and others, which were to become useful but minor contributors to the output, were found in the South Alligator area, NT, in the early 1950s. Treatment plants for the production of uranium oxide were erected at Port Pirie, where for several years rather high-cost material was produced from ores mined at Radium Hill; at Rum Jungle, where the plant remained in operation treating stockpiled ores until 1971; at Moline, NT which, after fulfilling the last part of an overseas contract for uranium, was modified to treat Pb-Zn-Ag ores from Mount Evelyn, pending resumption of uranium mining; and at Mary Kathleen which began operating in 1956 and was placed on care-and-maintenance in 1963.

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

Reserves have been sufficient for any likely domestic need. When Mary Kathleen was closed down, the company stated that more than 3 Mt of commercial-grade ore remained in the reserves; additional exploration increased this to more than 5 Mt at an average grade of 1.2 kg/tonne U_3O_8. Up until 1964, Mary Kathleen had produced oxides worth $90 million.

On the other hand the deposits at Rum Jungle were mined out and the plant continued to operate on stockpiled ore (and stockpiled the uranium oxide product) in a program that was completed in 1971. 1625 short tons of U_3O_8 was produced during the life of the Rum Jungle plant, and the total revenue over the period of operation was $42 million.

Meanwhile, the easing of the total export embargo by the Commonwealth Government in 1967 stimulated prospecting for new reserves, with notable success. New deposits were found in the Westmoreland area, NW Qld; near Lake Frome and at other localities, SA; at Yeelirrie, WA; and, of prime importance, the substantial deposits at Ranger 1, Nabarlek, Koongarra, and Jabiluka about 230 km east of Darwin, in a major new uranium province in the Northern Territory. Reasonably assured resources of uranium ore extractable at costs up to $US80/kg U were assessed at June 1978 by the AAEC to be 290 000 tonnes U, which is about 18 percent of the world known resources extractable at that cost. This figure excludes the apparently large quantities of uranium that have been discovered recently at the Olympic Dam prospect on Roxby Downs Station, SA.

21

The Mary Kathleen mine and mill reopened in 1976 after extensive modification and 359 tonnes of uranium in yellowcake was produced during the year. In 1979, output was 707 tonnes U in yellowcake.

A mill to produce uranium oxide at Ranger, with an initial capacity of 3300 short tonnes/year of U_3O_8, is being constructed. The Ranger Uranium Environmental Inquiry produced its first report on this project in November 1976 and its second and final report in May 1977.

Operations at Nabarlek and Ranger uranium mines were officially opened in early June 1979. Mining of the Queensland Mines Ltd Nabarlek orebody was completed by the end of the year and the ore will be treated on site over the next eight years at a rate of about 1100 tonnes of U_3O_8/year. Full production at Ranger should begin by late 1981.

Western Mining Corporation Ltd expects that the proposed Yeelirrie project in WA will begin production in 1985 at an annual rate of 2500 tonnes of U_3O_8.

There was a dramatic increase in world demand for uranium in 1975 and 1976, with prices for spot sales increasing from $US10.50/lb of U_3O_8 in 1974 to about $40/lb of U_3O_8 at the end of 1976. The increased prices reflected the belief that there could be a shortage in the mid-1980s. Prices have remained at $US42.50 - 44.00/lb of U_3O_8 until June 1979, then began to fall, and by the end of 1980 were about $US28/lb.

Australia is well endowed with uranium resources, which, in the 'reasonably-assured, plus estimated-additional' category account for about 12 percent of the total in the western world. The bulk of known reserves of uranium in the western world are in USA, South Africa, Australia, and Canada.

Black coal

The last 15 years has seen a spectacular increase in the growth of the Australian black coal industry. The main catalyst for this growth has been the coking-coal export market which has resulted in the development of several large open-cut mines in the Bowen Basin of eastern Queensland.

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 percent of Australia's demonstrated economic resources of black coal is in these two areas. These coals are of prime importance both as sources of coking coal for domestic and world markets and for electricity generation.

In 1979 Australia was the ninth-largest black coal producing nation, accounting for about 3 percent of world production of saleable coal; raw coal production increased to 93.0 Mt for a saleable coal output of 75.0 Mt.

The State producing the largest amount of coal is New South Wales, accounting for 55 percent of production. The main growth in the last decade, however, has been in Queensland which now produces 40 percent of the national output. Rapid growth in Queensland has been based on the development of large-scale open-cut coking coal mines; 88 percent of Queensland's production now comes from open-cut mines. The bulk of production takes place in the Bowen Basin in eastern Queensland; most of the coal produced is medium volatile coking coal for export. Smaller quantities of non-coking coal are mined at or near Blair Athol, Callide, Ipswich, and Maryborough for use by electric power stations or local industry.

Coal mined in New South Wales is bituminous and nearly all is mined in the Sydney Basin. In 1979, underground mines accounted for 75 percent of production. More than 60 percent is high-volatile soft-coking coal and steaming coal, most of which is mined in the Singleton-North West and Newcastle districts; smaller quantities are mined in the South Maitland area and in the Western district around 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.

Low-volatile and medium-volatile, or premium hard-coking coals, are mined in the South Coast and in the Burragorang Valley districts. About one-third of this coal is used at the Port Kembla steelworks and the rest is exported.

Minor quantities of non-coking coal are also mined at Gunnedah, and Ashford.

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). Minor quantities of non-coking coal are mined for use by local industry at Fingal in Tasmania.

In 1979, consumption increased to 34.9 Mt mainly because of an increase in consumption for electricity generation, in the iron and steel industry and in alumina refining. Consumption in electricity generation accounted for 63 percent of total consumption, in the iron and steel industry for 26 percent and in alumina refining for 3 percent.

Australia is a major exporter of black coal. In 1979 it was the third-largest exporter of black coal; the 41.1 Mt exported accounted for about 18 percent of world trade and was valued at about $1612 million, making coal Australia's largest single export earner.

Exports to Japan rose to 27.2 Mt in 1979 consisting of 25.6 Mt of coking coal and 1.6 Mt of steaming coal. The remaining coal, comprising about 9.1 Mt of coking coal and approximately 4.7 Mt of steaming coal, was exported mainly to Europe and Southeast Asia (totals disagree because of different sources of data).

The need in the coming years to conserve certain energy sources, especially oil and gas, because of depletion, will result in a swing away from these energy forms to coal, nuclear, and possibly solar power. Only a limited number of countries have the potential to substantially increase their coal exports to cater for the expected increase in requirements. For coking coal it would appear that Australia and Canada have the greatest potential, whilst for steaming or non-coking coal it would appear that Australia, South Africa, and possibly China have the greatest potential to cater for this rapidly expanding market. Because of the limited number of countries able to supply this additional coal it is expected that Australia's share of the export market will rise substantially and could easily double by 2000. Our known resources are sufficient to allow us to continue as a major exporting country for several decades to come.

Brown coal

Australia's major economic deposits of brown coal (more than 98 percent of demonstrated economic 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 the brown coal deposits in Gippsland, and at Bacchus Marsh, Altona, and Anglesea in Victoria, the recently discovered deposit at Kingston and two other deposits in the St Vincent's Basin, SA, other known deposits are either too small, too deeply buried, contain too much sulphur, or are otherwise unattractive as sources of energy.

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

Victoria is the only State which produces brown coal; the industry has reached a high degree of sophistication in mining, on-site development for power generation, briquetting, and char manufacture.

24

Production of raw brown coal in 1979 totalled 32.6 Mt; more than 95 percent 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 deteriorates rapidly and may ignite spontaneously when stockpiled, producers and consumers do not accumulate large stocks; consumption is roughly equivalent to output.

Apart from the possible markets linked with solvent-refined coal, activated carbon and char production, the major markets available to brown coal are power generation and, potentially, liquefaction. Investigations are currently being undertaken by Victoria's Brown Coal Research & Development Committee to determine the liquefaction potential of various Victorian brown coal deposits.

Our known reserves of brown coal are very large and greatly expanded production of brown coal would be possible in Victoria, subject only to environmental, manpower, and capital limitations.

Oil shale

Triggered by the first major increase in the world crude oil price in 1973, interest has been revived, in Australia and abroad, in oil shale as a potential source of liquid fuels. Discoveries in the last few years, especially in Queensland, have defined 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. Spasmodic production took place from some Australian deposits in New South Wales (e.g. at Glen Davis and Joadja) from 1865 until1952. The most intensified production was during a period of oil shortage and rationing during and after World War I; total production amounted to only 230 000 m^3 of shale oil.

Australia's inferred subeconomic resources of oil shale are estimated to be capable of yielding 230 000 million m^3 of oil. However, this huge inferred resource is mainly a single thin rock formation that is thought to underlie 423 000 km^2 of inland Australia, extending south from the Gulf of Carpentaria to southern Queensland and northeast South Australia. Formidable technical and other problems would need to be overcome to enable this resource to be upgraded to 'economic' status.

25

However, certain oil-shale deposits in Queensland are much thicker, are richer, are in geographically favourable locations, and thus at this stage can be regarded much more realistically as resources. The Rundle deposit near Gladstone, with stated reserves of 361 million m^3 of recoverable oil, is the subject of a comprehensive feasibility study by Esso Exploration and Production Australia Ltd with a view to production being commenced in 1985. Australia's demonstrated resources of oil obtainable from oil shale at present stand at 2629 million m^3, but at present all of this is still classified as subeconomic; most of the demonstrated resources are in Queensland. Rundle and Julia Creek, Condor, Stuart, Yaamba and Duaringa being the most important of these.

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 oil-shale exploitation. However, surface extraction methods are now far more advanced than in the past, and one form of in-situ extraction is nearing 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 percent of our ferroalloys are imported.

Iron and steel

Production of iron ore for iron and steelmaking in 1979 was about 92 Mt, an increase of 10 percent on the output in 1978. Production of raw steel in Australia increased to 8.1 Mt in 1978, 7 percent higher than in 1978; production of pig iron increased by 6 percent to 7.8 Mt in 1979. Steel output increased in 1979 in response to a substantial increase in demand for steel products for use in the development of new power generation coal-mine and related transport projects. The increase in demand led to shortages of some products. Steel output at Whyalla and Port Kembla increased by 13 percent and 16 percent to 1.27 and 4.85 Mt respectively more than balancing a 12 percent decrease in output at Newcastle to 2.00 Mt where production was adversly affected by industrial disputes, blast furnace modifications, and other technical difficulties.

26

Exports of crude steel, including ingots, blocks, lumps, blooms, billets, and slabs, decreased by 39 percent to 610 803 tonnes valued at $104 million in 1979 because steel normally exported was required to meet domestic shortages. Exports of crude steel plus rolled and shaped iron and steel products were valued at $558 million in 1979 and imports at $305 million. Production capacity for pig iron is surplus to domestic needs and exports were valued at $72 million in 1979.

Iron and steelmaking absorbed 11.5 Mt of iron ore in 1979. The main sources were the Middleback Ranges, SA, and Mount Whaleback and Koolyanobbing, WA. A small charcoal-iron plant at Wundowie near Perth, which produces special grades of pig, using charcoal as a reductant, consumed 89 500 tonnes of ore from Koolyanobbing in 1979; 26 400 tonnes of 'iron ore', mainly magnetite, was imported chiefly from Canada in 1979 for use as a heavy medium in the coal washing industry. In addition to the iron ore consumed in Australia, about 78 Mt of ore, including 8.5 Mt of pellets, was exported, 4 percent more than the 75 Mt of ore, including 7.6 Mt of pellets, exported in 1978. Exports were principally from Western Australia; Tasmania continued to export pellets. The f.o.b. value of exports in 1979 was $1008 million, 11 percent more than in 1978.

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

To illustrate the spectacular change in our reserves it may be noted that in 1959 the official estimate of demonstrated reserves amounted to only 359 Mt. At that time exploratory drilling in several States had raised hopes that intensified search might reveal some worthwhile new deposits. Among the principal prospects at the time were: Savage River in western Tasmania, where airborne magnetic surveys 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, Western Australia, where drilling had shown a more substantial body than was indicated by outcrop and surface sampling.

27

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 Goldsworthy, and Koolanooka east of Geraldton, was based on hematite deposits, but limonite deposits at Robe River and hematite-goethite (goethite is an hydrated iron oxide, FeO.OH) deposits near Mount Whaleback particularly are also now 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, an assessment by BMR has placed economic resources in the Hamersley Iron Province alone at around 15 300 Mt within total economic resources for Australia of 18 000 Mt. In other words, since 1959 our known resources have increased some 48-fold at least and all anxiety for adequate domestic supplies has been removed for many years to come.

However, not all the increase in reserves has come from the discovery of new deposits. Metallurgical research aimed at making possible the use of low-grade ores, of which there is an abundance in several States, has also contributed to the changed picture and may have a greater long-range effect than is presently realised. Major expansion projects by the Mount Newman Joint Venture and by Hamersley 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 lift production.

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

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

Investment in iron and steel plant is now running at more than $320 million annually.

New major plant items commissioned since 1962 are a ferroalloy plant and expansions at Bell Bay, Tas.; an electrolytic tinning line, a high-speed pickle line, a second hot-roll processing line, a new blast furnace and a basic -oxygen steelmaking plant and continuous slabcaster at Port Kembla, NSW; a basic-oxygen steelmaking plant and associated rolling mill facilities, as well as a continuous steel-casting plant, at Newcastle. At Whyalla a second blast furnace and an integrated steel plant opened in 1965, and an iron ore pelletising plant was commissioned in 1968. At Kwinana, the first stages of an iron and steel complex were constructed, and a cold rolling plant was completed at Unanderra, where a vacuum degassing plant also began operating. BHP outlined plans in 1979 for a $90 million expansion program at Whyalla, a blast furnace modification program at Kwinana, and improved steelmaking quality control facilities at Newcastle. Further plans were outlined in 1980 for a $147 million new coke ovens battery at Port Kembla and for a new 200 000 tonnes/year capacity steel mill at Geelong, Victoria, comprising an electric arc steelmaking furnace and continuous billet caster.

Non-communist world consumption of steel in 1979 was estimated by the International Iron & Steel Institute to have remained below peak consumption of 491 million tonnes in 1973. World production increased by 4 percent to a record 746.1 million tonnes.

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 15 kg of manganese dioxide for every tonne of steel produced. It is also a hardening constituent in many grades of steel; and high-quality manganese dioxide is used in the manufacture of dry-cell batteries. In 1979, 445 000 tonnes of manganese ore was required by our industries.

Our self-sufficiency in this mineral for most purposes has only recently been proved. For many years the known Australian resources of manganese ore were small. Between 1916 and 1927, the steel industry depended upon deposits in New South Wales; as these were worked out, small deposits in South Australia took their place from 1940 to 1944; subsequently Western Australia became the main source. In the 1950s cheap supplies became available from South Africa, and Australian production slumped, but has recovered again to meet the requirements of a developing export trade, mainly to Japan. As with iron ore, manganese was subject to a long-standing embargo on exports, but this was partly relaxed in 1956 to allow for shipments of a portion of any new discoveries made. This 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 revealed, 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 have now established an open-cut mine and treatment plant. Shipments of ore from Groote Eylandt have increased to supply most of Bell Bay's ferromanganese requirements, plus an export surplus. This deposit can supply all of Australia's requirements for metallurgical-grade ore for a long period to come; however, we have no supplies of battery-grade ore and continue to import this at the rate of about 1600 tonnes/year. In addition increasing quantities of electrolytic manganese dioxide (1245 tonnes in 1978-79) are being imported from Japan and USA for battery manufacture.

Australian production of manganese ore in 1979 was about 1.7 Mt. Exports normally exceed 1.0 Mt annually, mainly to Japan and European markets. Imports other than battery-grade ores have shown a marked decline from 1965 and were almost 119 000 tonnes in 1979. Australia's production of high-carbon ferromanganese now satisfies local demand, but imports of other grades including powder totalled 16 985 tonnes in 1979. Since the cessation of production in the Port Hedland district of Western Australia in 1973, Groote Eylandt is now the only large-scale producer of manganese ore.

Nickel (Ni)

Nickel is used mainly as an alloy in stainless steel (about 40%) 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 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 in terms of worldwide production so far) is the iron-nickel sulphide pentlandite ($(Fe,Ni)_9S_8$), although most of the world's known reserves are contained as oxides and silicates in laterite, a tropical weathering product of certain rocks. Following the initial discovery, by Western Mining Corporation Ltd, of sulphide nickel ore

30

at Kambalda in 1966, other companies made important finds and by the end of 1974 fourteen nickel mines were in production. By the end of 1979 five of these had stopped producing but four new mines had started up. WMC remains the largest producer of nickel ore from its group of mines at Kambalda, where proved and probable reserves at June 1979 were estimated to be 21.0 Mt averaging 3.28% Ni. In 1979 WMC produced a total of 35 053 tonnes of nickel in concentrates (nickel contained in ore produced at the Nepean mine, owned by Metals Exploration Limited, is included in the WMC figure).

The Greenvale lateritic mine (Metals Exploration Queensland Pty Ltd/ Freeport Queensland Nickel Inc.) in northern Queensland produced 2.1 Mt of ore from which 20 476 tonnes of nickel was recovered in sintered nickel oxide and nickel-cobalt sulphide. Proved ore reserves at this mine are 30.4 Mt averaging 1.31% Ni.

Windarra Nickel Mines Pty Ltd (WMC 50% - Shell Company of Australia Ltd 50%) has been on care-and-maintenance since early in 1978 because low nickel prices made the operation uneconomic; however, the partners are carrying out an extensive underground development program to ensure that full-scale production can be rapidly attained once the area is re-opened.

The Redross mine (Anaconda Co. - Conzinc Rio Tinto of Australia Ltd) ceased operations in 1978 because of lack of ore.

Spargoville Location 3 (Selection Trust) produced 4271 tonnes of nickel in ore during 1979. The mine ceased production in early in 1980 because ore reserves were exhausted.

One new mine, Agnew, operated by Agnew Nickel Co. Pty Ltd (60 percent Seltrust Mining Corp Pty Ltd, 40 percent MIM Holdings) started producing nickel concentrates in mid-1978. Original studies called for the production of 30 000 tonnes/year of nickel but because of a recession in the nickel industry initial production began at the rate of 10 000 tonnes/year of nickel in concentrate but as announced in 1979 this is now being increased to 15 000 tonnes/year by 1984. Proved ore reserves at the mine are 45 million tonnes averaging 2.05 percent nickel.

In addition to the projects already mentioned, whose output is more than sufficient for Australian requirements, there are several large but low-grade deposits which at the present time are not economically viable. A large lateritic deposit occurs at Wingellina in Western Australia near the northern sector of the South Australian border. A large disseminated sulphide province at Mount Keith, south of Wiluna, shows promise for delineation of high grade resources following the intersection of high grade sulphides in 1980 during drilling.

31

Production of nickel concentrates began in June 1967 at Kambalda and output for that year was 2060 tonnes of contained nickel. In 1979 Australian mine production of nickel was 69 709 tonnes. Australia is now the third-largest producer of nickel in the non-Communist world. In 1979 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 with an output of 15 000 tonnes/year of metallic nickel. Output in 1979 was about 21 900 tonnes but the plant has the capacity to produce 30 000 tonnes/year. WMC commissioned a nickel smelter at Hampton near Kalgoorlie in 1972 with a capacity of about 200 000 tonnes/year of concentrate, but this has since been increased to 450 000 tonnes/ year 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 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 the product has always been exported. Domestic consumption is small and there should be little difficulty in meeting Australian requirements for ore from known resources whenever the need arises, although we do not currently produce metal or alloys.

The principal deposits are in Tasmania and Queensland. Wolframite comes mainly from Avoca, Tas., where the Aberfoyle and Storey's Creek mines have been the principal producers; and from Mount Carbine in northern Queensland where Queensland Wolfram Pty Ltd produces wolframite and minor scheelite. A major deposit of scheelite has been mined for many years on King Island, Bass Strait, where known reserves have increased to 6.7 Mt, averaging 0.8% tungstic oxide (WO_3).

Australian production in 1979 (expressed as concentrates of 65% WO_3 content) was 6194 tonnes. Recent enhanced prospects on King Island and of Queensland Wolfram at Mount Carbine promise higher production of scheelite in the future even if operations are stopped at the high-cost mines in the Avoca area. The scheelite concentrate formerly produced at King Island contained sufficient molybdenite (MoS_2) to attract a penalty. A plant to produce artificial scheelite has been constructed there, and the resulting by-product MoS_2 is being sold.

32

Australian consumption of WO_3 has never exceeded 100 tonnes/year, its main use being in the manufacture of tungsten-carbide-tipped tools.

Molybdenum (Mo)

Molybdenum is being used increasingly 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 being used increasingly 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. In 1979 domestic production of commercial-grade molybdenite was about 40 tonnes. Imports of molybdenum ore and concentrates decreased in 1979 to 243 tonnes, but imports of ferromolybdenum increased to 220 tonnes; imports of molybdenum oxide and hydroxide decreased from 31 tonnes in 1974 to less than 1 tonne in 1975; figures are not available for later years.

Most of the molybdenite deposits in Australia occur in pipes, for which development to any depth is costly. One exception is at Yetholme, NSW where a disseminated contact deposit aggregating some 800 tonnes of molybdenite lies at shallow depth beneath comparatively thin overburden. A discovery of extensive disseminated low-grade molybdenite at Mount Pleasant, 30 km southeast of Mudgee, was announced by CSR Ltd in September 1979. Considerably more drilling is needed before any decisions can be made about development. During World War II the Commonwealth sponsored exploration for new deposits, but results were generally not encouraging. Production from Wolfram Camp, Qld, resumed in 1979, and a deposit at Mount Mulgine, WA, is under investigation. Recovery of molybdenum as a by-product from treatment of scheelite at King Island, began in 1978, and could supply part of our demand.

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

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 has recently averaged 10 000 tonnes, most of which is normally imported. In 1979, 11 884 tonnes of chromite was imported, mainly from South Africa and the Philippines. Imports of ferrochrome, mainly from South Africa, decreased to 13 826 tonnes in 1979. Production of chromite at Barnes Hill, Tasmania in 1979, mainly for use in the foundry industry, amounted to 1855 tonnes.

The largest known Australian deposit of chromite is at Coobina, in the Ophthalmia Range, WA. The only recorded production was between 1952 and 1957 when 14 500 tonnes 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 ferrochrome were produced at Newcastle until the closure of that plant at the end of 1974, all requirements are now imported. In time of emergency we could almost certainly revive our domestic ore production to meet the demand.

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. None has been produced in Australia and local consumption is negligible, but recent exploration has indicated possible economic hard-rock deposits in Western Australia, and potential supplies as a by-product of the treatment of oil shales in northwestern Queensland. Agnew Clough Ltd started work on construction of mine access roads to its Coates Siding, WA deposit in mid-1978; commissioning of a vanadium pentoxide production plant began in mid-1980 and full operations at an initial rate of 1130 tonnes/year were planned in late 1980. Overseas sources of supply, are mainly USA, South Africa, Finland, and Southwest Africa. World production in 1979 was about 32 520 tonnes.

BASE METALS

Copper (Cu):

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

The Australian scene is dominated by Mount Isa, which produced 72 percent of the total in 1979 and has reserves sufficient to support a high rate of production for over 25 years. Other important centres are Mount Lyell, Tas; Cobar, NSW; and Mount Gunson, SA. Production from the Woodlawn copper-lead-zinc-silver mine in NSW began in late 1978, and production from the Teutonic Bore copper-zinc mine in Western Australia is expected to begin in mid-1981.

The full potential of the Mount Isa deposits was not realised until the early 1950s, although copper was mined for emergency purposes from some minor lodes during the war years. After the discovery by drilling of high-grade copper lodes, a major new enterprise got under way in 1953 and output has since grown steadily. The Mount Isa-Cloncurry region of Queensland is the most important copper mining province in Australia both historically and on the basis of mine production; over 2 million tonnes of copper has been produced since 1884, most coming from the Mount Isa mine.

Mine production increased steadily for many years because of expanded output from Mount Isa and Mount Lyell and the commissioning of several new mines in the late 1960s and early 1970s. Record levels of production were achieved in 1973 and 1974. In 1979, for the first time since 1974, production exceeded the 1973 level.

Exploration diamond drilling continued on Western Mining Corporation's large Olympic Dam prospect at Roxby Downs, SA during 1979 and 1980 where an extensive zone of copper-uranium-gold mineralisation from 8 to 248 m thick, with probable economic grades, has been intersected about 350 m below the surface.

In March 1979 WMC announced the discovery of another deposit of copper-zinc mineralisation, near Benambra, in northeast Victoria. This deposit is 4 km northeast of a similar deposit at Wilga.

In November 1979, Mount Isa Mines Ltd announced that in the Balcooma area, northwest of Greenvale, in north Queensland four of eleven diamond drillholes had intersected copper-silver-gold mineralisation.

In August 1980, the Electrolytic Zinc Co. of Australasia Ltd and Golden Grove Mining NL announced the discovery of a second area of significant copper, zinc and silver mineralisation north of its Gossan Hill copper-silver deposit. There appear to be two separate zones: one predominantly of copper and the other of zinc, to the west of the copper zone.

Australia has two copper refineries - at Port Kembla and at Townsville. A third at Mount Lyell was closed down in 1969. The refinery at Townsville (operated by Copper Refineries Pty Ltd, a wholly owned subsidiary of MIM Holdings Ltd), with an annual capacity recently expanded to 155 000 tonnes, is by far the larger. It was commissioned in 1959 and refines the whole of the Mount Isa output. In 1979, 81 percent of the copper in copper concentrates produced in Australia was processed in Australia to blister or refined metal. It is expected that the level of domestic processing will rise during the next decade as mine production at Woodlawn and refinery output at Port Kembla increase and as the Tennant Creek smelter is recommissioned.

Details of copper in all mine products in 1979 are as follows:

		Tonnes (metal)
Queensland		
Mount Isa	169 953	
Mount Morgan	2 597	
Others	1 156	173 706
New South Wales		
Cobar	5 989	
Broken Hill lead-zinc-silver mines (by-products)	3 451	
Woodlawn	9 093	
Others	7	18 540
Tasmania		
Mount Lyell	18 683	
Others	4 305	22 988
Western Australia		
Nickel mines (by-product)	3 388	3 388
South Australia		
Burra	2 763	
Mount Gunson	10 302	13 065
Northern Territory		
Tennant Creek mines	5 739	
		5 739
Total		237 421

Lead (Pb)

Lead and zinc 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)), which are mined in the same operation. The lead is then separated from the zinc by crushing and concentration. Galena almost always contains silver; it is the most important ore of lead and one of the most important sources of silver.

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 her already dominant position was reinforced by the discovery and exploitation of Mount Isa in the years following 1923. Australian metal mining began with silver-lead in South Australia in 1841. We have been amongst the world's leading producers of lead for many years and in 1979 with a production of 421 581 tonnes we ranked as the third-largest producer in the world behind USA and USSR. Our known resources are sufficient for us to continue as a major exporting country for several decades.

Mine production has run uniformly high in recent years, after being below capacity in 1970-71, when it was affected by an international arrangement in which a substantial part of Australian production was voluntarily curtailed. Output in 1979 was 5 percent above production recorded in 1978, mainly because of increased output at Woodlawn and a return to more normal levels of production at Mount Isa and the NBHC mine at Broken Hill.

Details of lead in all mine products from the States in 1979 are as follows:

		Tonnes
New South Wales		
All Broken Hill mines	224 745	
Woodlawn	17 610	
Cobar	2 002	244 357
Queensland		
Mount Isa	155 021	
Others	-	155 021
Tasmania		
Read-Rosebery		22 160
Other States		43
		421 581

37

Most of our lead concentrates are smelted in Australia. There are smelters at Mount Isa, Qld, and Cockle Creek, NSW, which together produced 169 452 tonnes of lead in lead bullion in 1979, and a smelter and refinery at Port Pirie, SA, which produced 232 791 tonnes of refined lead. Output of refined lead from other secondary producers totalled 24 800 tonnes. Domestic consumption increased to 78 700 tonnes (including 36 000 tonnes from scrap); increased sales were recorded for most end uses.

Lead acid batteries continue to be the most important lead market and account for 45-50 percent 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 slow-down. 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 some countries has resulted in a decrease in consumption of lead in tetra-ethyl lead. In view of the introduction of similar regulations in other countries it is now inevitable that the amount of lead so consumed will have fallen considerably by the early 1980s.

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. In 1969, mine production reached a record 510 000 tonnes. Output in subsequent years has been reduced by voluntary cutbacks, industrial problems, and lower ore grades. Mine production increased by 12 percent in 1979; increased output at Woodlawn and Mount Isa, and a return to a more normal production level at the NBHC mine at Broken Hill, more than offset lower output at most other mines. Most Australian deposits contain both lead and zinc, and the increased lead demand resulted in a continuing high level of mine production of zinc and a resultant build-up of stocks.

Details of 1979 production are as follows:

		Tonnes
New South Wales		
Broken Hill mines	269 601	
Woodlawn	49 004	
Cobar	6 676	325 281
Queensland		
Mount Isa		128 647
Tasmania		
Read-Rosebery		75 229
		529 157

There are three zinc refineries in Australia - a large electrolytic plant (capacity 210 000 tonnes/year) at Risdon, Tas. based on hydroelectric power; an Imperial Smelting Process plant (capacity 75 000 tonnes/year) at Cockle Creek, NSW; and at Port Pirie, SA, an electrolytic refinery (capacity 45 000 tonnes/year), which recovers zinc from a slag dump derived from the treatment of lead concentrates.

About 60 percent of our total zinc concentrates (all from Tasmania, and some from Broken Hill and Mount Isa) was treated at these plants in 1979. The remainder of concentrates from Broken Hill and Mount Isa was exported. In 1979, production of refined zinc was 294 766 tonnes (including 5000 tonnes from secondary sources). Domestic consumption increased to 102 400 tonnes of refined zinc, of which 97 400 tonnes was of primary origin. Sales of primary refined zinc for galvanised sheet steel continued to be above the very low total recorded in 1977 but were still below the 1976 level. This was mainly because of increased sales of 'zincalume', galvanised sheet steel coated with an aluminium (55%)-zinc (43.5%) coating in place of the traditional zinc coating.

Growth in both the domestic and world zinc markets 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 is claimed to have twice the life of the ordinary galvanised surface), prospects for growth appear limited.

Zinc die-castings, the second-largest end use for zinc in Australia, have also 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 for vehicles.

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 the only areas where future growth is 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 in 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 reached a record 12 571 tonnes in 1979. Production of primary refined tin, after reaching a peak in 1972 of 7027 tonnes, decreased largely because of changes in the type of concentrate available to the smelter, and was 5423 tonnes in 1979.

Imports in 1979 were 5 tonnes of refined tin; exports were 2108 tonnes of refined tin and 12 898 tonnes of concentrates containing 6435 tonnes of tin. Estimated consumption of primary refined tin in the same year was 3387 tonnes. Consumption in 1980 will probably be about the same.

Tinplate accounts for about two thirds of the domestic consumption of tin. Tin alloys have many uses - soft solder (tin and lead), bronze, bearing metal, gun metal, die-casting, and pewter. Tin salts are used in ceramic enamels, plastics, wood preservatives, and pesticides. Production of hot-dipped tinplate commenced at Port Kembla in 1957; an electrolytic line was commissioned in 1962 and another in 1973, and the hot-dipped line closed in 1972. Technological advances have resulted in a progressive decrease in the amount of tin consumed per unit area of tinplate produced. Tinplate is susceptible to substitution by other packaging materials, but increases in energy costs or costs of raw materials have adversely affected the competitiveness of substitutes such as aluminium and plastics.

Associated Tin Smelters Pty Ltd, operating at Alexandria, NSW, is the only domestic producer of primary refined tin. Annual smelter capacity is rated at 15 000 tonnes of concentrates. However, the increasing proportion of concentrates from lode mining (see below) means that the output capacity of refined tin has been reduced: concentrates from lode mining have a lower tin content and contain more deleterious impurities than those from alluvial mining. The smelter has installed plant to enable it to smelt such concentrates more efficiently. Greenbushes Tin NL commissioned an electric smelter, with a capacity of 2000 tonnes/year of concentrate, at Greenbushes in 1980.

Traditional treatment methods are not suitable for ores in which the cassiterite is very fine grained, especially if other metal sulphide minerals are also common in the ore. A process known as matte fuming gives promise that such ores can be economically treated. Aberfoyle Limited began operating a pilot scale matte fuming plant in 1980 at the Kalgoorlie nickel smelter of Western Mining Corporation Limited.

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

Exploration for tin deposits greatly increased in the late 1970s, and several promising new discoveries were announced in 1980, although none has as yet been declared economic. Published reserves in most deposits are sufficient for only a few years, but further exploration and continuation of recent high prices could result in reserves being increased. However, the Renison mine contains more than half the total reserves, its annual production is more than Australian consumption, and the mine alone has the potential to supply Australia's requirements of tin to the turn of the century at least.

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

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 our 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 reserves, 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 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. Production of ore from Weipa, Jarrahdale, and Gove has mounted rapidly and in 1979 was 27.6 Mt. Australian reserves are now known to be very large, at least 6200 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 13 Mt/year, while those at Gove, NT can handle 5 Mt/year.

On the treatment side, developments have also been rapid, and imports of alumina have been relatively low (4210 tonnes in 1979) and used principally for purposes other than aluminium production since the commissioning of the Gladstone alumina refinery in 1967 (present capacity 2.4 Mt/year). An alumina plant at Kwinana, near Fremantle, WA, with a present capacity of some 1.4 Mt/year, is supplying feed to the smelter of Alcoa of Australia Ltd at Geelong. Alumina is also being shipped from Kwinana to Japan, USA, and Bahrain. Alcoa commissioned a second refinery at Pinjarra, WA in 1972, with an initial capacity of 250 000 tonnes of alumina/year, which has been expanded in stages to its present capacity of about 2.4 Mt/year. Alcoa has begun to build a third refinery at Wagerup, about 120 km south of Perth. Initial capacity will be 500 000 tonnes/year although there is provision for expansion to 2 Mt/year.

Queensland Alumina Ltd (a partnership of CRA, Kaiser, Alcan, and Pechiney) commissioned an alumina plant in 1967 at Gladstone, Qld, which processes bauxite from Weipa. The plant had an output in 1967 of some 600 000 tonnes/year of alumina; this has since been expanded in stages to 2 400 000 tonnes/year. Part of this production is used as feed for a smelter at Bluff, New Zealand, completed in 1971 by Comalco in partnership with Showa Kenko KK and Sumitomo Chemical Company of Japan. The alumina requirements of Comalco's smelter at Bell Bay, Tas. and of Alcan Australia Ltd at Kurri Kurri, NSW are also provided by Gladstone, and the bulk of the remainder of Gladstone's output is sold overseas.

Early in 1969 an agreement was completed between the Australian Government and Swiss Aluminium Australia Limited and an Australian group, Gove Alumina Ltd, for a project at Gove, NT, to produce 1 Mt of alumina and up to 2 Mt of bauxite for export; initial shipments of bauxite began in June 1971 and the alumina refinery came on stream in June 1972 and reached its rated capacity of 1 Mt/year by mid-1973; operating capacity is currently about 1.2 Mt/year.

Alcan Australia Ltd established a primary smelter at Kurri Kurri, NSW in 1969, with an initial production of 30 000 tonnes of metal, which reached 45 000 tonnes/year in 1971, and 68 000 tonnes/year by 1979. The company is continuing with expansion to 90 000 tonnes/year by 1981 and to 135 000 tonnes by 1983.

Alcoa's Geelong smelter, which came into production in 1963 with an initial annual capacity of 20 000 tonnes of metal, was expanded in stages to its current capacity of about 100 000 tonnes, which is to be increased to 165 000 tonnes/year by early 1981. Alcoa announced in June 1979 that a site near Portland, Vic., had been selected for a new smelter of 132 000 tonnes/year capacity initially. Construction began in 1980 and will be completed in 1983.

Expansion of the Bell Bay smelter of Comalco Ltd, to a capacity of 112 000 tonnes/year, was completed in 1977. Comalco is constructing an aluminium smelter at Gladstone, with an initial capacity of 103 000 tonnes/year in 1982 to be expanded to 206 000 tonnes/year by 1983.

Alcan Queensland Ltd plans to build a smelter at Bundaberg with an initial capacity of 100 000 tonnes/year by 1984.

Alumax Inc. has announced that it is to study the feasibility of establishing an aluminium smelter with a capacity of 200 000 tonnes/year at Lochinvar in the Hunter Valley of New South Wales.

A partnership consisting mainly of Aluminium Pechiney Australia Pty Ltd and Gove Alumina Ltd (51 percent CSR Ltd) is to establish a smelter at Tomago, NSW, north of Newcastle. Initial capacity will be 112 000 tonnes/year by 1983, to be expended to 224 000 tonnes/year by 1985.

The current position in Australia therefore is: resources of bauxite of at least 6200 Mt and plant capacity for the production of 7.4 Mt of alumina and of 280 000 tonnes of aluminium, with further expansions in train or planned.

Titanium (Ti)

Australia's resources of the titanium minerals, rutile (TiO_2) and ilmenite ($FeTiO_3$), are considerable. Domestic recoverable reserves are put at about 9 Mt of rutile and 46 Mt of ilmenite, although almost half of the east-coast reserves of rutile are currently unavailable for mining because of environmental considerations.

In 1979 Australia supplied about 81 percent of world output of rutile concentrates and about 30 percent of the world's ilmenite concentrates.

The traditional uses of rutile have been in the manufacture of welding rods and the production of titanium metal; since the early 1960s, by virtue of the chloride method of processing, rutile has been used in the manufacture of pigment for high-gloss white paint, an outlet which now accounts for about 60 percent of total rutile consumption. The use of ilmenite is virtually confined to pigment manufacture. However, the commercial application of processes by which ilmenite is upgraded to approach rutile in TiO_2 content (beneficiated ilmenite or synthetic rutile) provides a feed for either pigment or metal via the chloride process; beneficiated ilmenite now complements supplies of natural rutile. Although installed world capacity for beneficiated ilmenitewas rated at about 300 000 tonnes in 1979, only a proportion of this capacity (that in Australia, India, Japan and Taiwan) was actually used because of technical difficulties and high production costs.

The principal Australian production of rutile is from sands on and adjacent to the beaches of the eastern coast. The discovery in 1971 of old shoreline deposits of rutile, zircon, and ilmenite near Eneabba, 270 km north of Perth, constituted a major additional supply of rutile. Commercial production of rutile from this source began in 1975 and installed capacity for rutile production in the area is now about 150 000 tonnes/year. In 1979, production from this source accounted for about 37 percent 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 principal ilmenite industry has been built up along the south-western coast of Western Australia. The quality of the ilmenite from this source is most satisfactory for the manufacture of titanium white, and as ilmenite is the main heavy-mineral constituent of the sands, its recovery forms the basis of the 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 42 000 tonnes of beneficiated ilmenite has been achieved. The plant is now based mainly on ilmenite from the company's operation at Eneabba, supplemented with secondary ilmenite produced at Capel. A semi-commercial plant with an annual capacity of about 13 000 tonnes/year of synthetic rutile, closed down in 1975, was reactivated at the end of 1979. Both rutile and anatase pigments are produced in Australia at Burnie, Tas., and at Bunbury, WA. 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 60 000 - 70 000 tonnes/year. Ilmenite concentrates are exported from Bunbury and Geraldton, where substantial bulk loading facilities are available.

Zirconium (Zr)

Australian resources of zirconium, in the beach-sand mineral zircon ($ZrSiO_4$), are considerable and are almost twice those of rutile. Again, however, almost half of east-coast reserves are unavailable to mining because of environmental considerations. Zircon is produced as a co-product of rutile mining along the east coast and in the Eneabba area, WA, 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 1979 produced 61 percent 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 but became firm in 1973; as temporary assis-

45

tance to the industry, the Commonwealth Government early in 1971 supported a stockpiling scheme initiated by industry by controlling the maximum price of zircon in export contracts. The position of oversupply was quickly reversed, and in 1973 Australia exported a record 431 000 tonnes of zircon concentrates. 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 view of the continuing adverse market situation, the floor price for zircon exports was reduced to the range $115-125/tonne, f.o.b. at the beginning of 1977. To allow more flexibility in approving zircon prices for export, normal export controls were re-introduced in March 1977. Following a period of oversupply, excess stocks have been liquidated, and the world supply-demand position is now in reasonable balance.

Australia will be self-sufficient in beach-sand minerals, particularly in ilmenite, at least to the turn of the century.

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 operations on both the east and west coasts of Australia. Notwithstanding the use of thorium in several US experimental reactors, large-scale nuclear uses in fast-breeder reactors are said to be many years off. Although research on the nuclear application of thorium continues, commercial 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.

An increasing interest in monazite results from its rare-earth content, particularly of cerium and yttrium. World demand for rare earths increased sharply in 1973, particularly for high-strength low-alloy steels used in oil and gas pipelines. In recent years, the pattern of rare-earth applications has changed from one based on the use of rare earths as catalysts to one more strongly oriented to metallurgical applications. Estimated percentage end-use applications in 1979 (compared with ten years ago) are: catalysts 26% (63.0%); metallurgy 43% (6.4%); glass and ceramics 31% (30.0%); TV electronics, nuclear, and miscellaneous less than 1% (0.6%). Cerium is also present in the mineral allanite ((Ce,Ca,Y)$(Al,Fe)_3$$(SiO_4)_3$(OH)), large quantities of which are found in the Mary Kathleen uranium deposit.

High-grade monazite concentrates are recovered from beach sands in Western Australia, Queensland, and New South Wales. The monazite recovered in the southwest corner of Western Australia is a by-product of ilmenite produc-

46

tion, but elsewhere of rutile and zircon production. Development of extensive mineral sands deposits commenced at Eneabba about 270 km north of Perth in 1973, and the area is now a major world source of monazite. In 1979 Australian production was 16 340 tonnes of concentrates containing about 15 139 tonnes of monazite, 89 percent of which came from Western Australia; Australian production was about 65 percent of total world output of monazite in 1979. All sales were exports before 1969, but a former uranium plant, purchased from the South Australian Government at Port Pirie, was commissioned in May 1969 to process monazite. In early 1972 an annual throughput rateof 1300 tonnes of monazite concentrate was achieved at the plant for the production of cerium and lanthanum hydrates, yttrium oxide, thorium sulphate, and tri-sodium phosphate. However, financial and market difficulties forced closure of the plant in mid-1972.

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

Antimony (Sb)

Antimony is used principally to impart hardness and stiffness in 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, as a flame retardant (as the oxide), and in the plastics industry.

Production of antimony in antimony concentrates in 1979 was 978 tonnes, nearly all of which was exported. In addition 560 tonnes of antimony from Broken Hill base-metal concentrates was recovered in antimony alloys produced at Port Pirie. In 1979, the Port Pirie lead refinery produced 13 631 tonnes of antimonial lead and 7544 tonnes of lead sheathing alloy containing 785 tonnes of antimony, of which 480 tonnes was recovered from scrap.

Exports of antimonial lead alloy in 1979, mainly to Belgium-Luxembourg, amounted to 8004 tonnes valued at $7 938 000. In early 1977 Quelar Chemicals established a small electrolytic antimony refinery in Brisbane. Production in 1977 was reported to be about 3 tonnes of metal, but the high energy costs involved made it uneconomic and the operation was placed on care-and-maintenance in early 1978. In 1979, 51 tonnes of antimony metal, valued at $138 000, was imported; mainland China was the main supplier.

Antimony ores have been produced in Australia since the middle of the last century, but most deposits have been worked out. Recently, the only significant production has come from mines in the Hillgrove area in northeastern New South Wales - in 1979 production was 942 tonnes of antimony in concentrates.

Exploration for antimony greatly increased under the influence of world shortage and record prices in 1969-70, but with the rapid decline in price in 1971, development has been concentrated on higher-grade deposits. The Blue Spec antimony-gold mine, 150 km southeast of Port Hedland, WA, began production in mid-1976. Planned output was 5.8 tonnes/day of 60%-Sb concentrates, amounting to 1270 tonnes/year antimony over a mine life of 28 months. However, problems were experienced throughout 1977 and the plant operated well below capacity. Recovery of antimony was lower than expected and the weak antimony market resulted in a build-up of stocks and a substantial operating loss, culminating in the closure of the mine in early 1978.

Australia is already self-sufficient in antimonial lead, but requires minor imports of high-purity antimony each year.

<u>Beryllium (Be)</u>

Beryllium is a lightweight metal processed mainly from the mineral beryl ($Be_3Al_2Si_6O_{18}$), good specimens of which may be marketed as gemstones (e.g. emerald is a variety 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 1967 was only 55 tonnes, containing some 6.9 tonnes of beryllium oxide. However, the same year saw exports totalling 637 tonnes of beryl, nearly half to Japan, obtained largely from stockpiled material in Western Australia; there has been no subsequent record of exports to Japan. Production was 20 tonnes of contained BeO in 1973 before falling to 9 tonnes in 1974. There was no production since 1974, although exports of beryl concentrates were resumed from Western Australia in 1977 and totalled 14 tonnes valued at $2839, all to USA; there were no exports in 1978 or 1979.

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

Lithium (Li)

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

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

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

Tantalum (Ta)-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, for tipped tool cutting purposes, and in anodes and grids for electronic equipment. Australia is an important producer of the ore (tantalite-columbite). This is from Western Australia, mainly as a co-product of tin mining at Greenbushes and Moolyella, and also from Wodgina. Greenbushes Tin, the main producer, is installing a plant to produce tantalum oxide and columbium oxide from concentrates and tantalum rich tin smelter slag. Production amounted to about 147 tonnes of combined concentrates in 1979, and was almost all exported. There is no domestic demand but if one arose in time of emergency, available supplies could most probably satisfy the requirement.

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 with the cheaper materials silicon and germanium. There is some production from tankhouse slimes in the electrolytic copper refinery at Port Kembla, but statistics of production are not available for publication. Peko-Wallsend Ltd produces concentrates containing gold, bismuth, copper, silver, and selenium at Tennant Creek. No payment was received in 1979 for selenium in concentrates exported to the Federal Republic of Germany and it is therefore not recorded as Australian production. Domestic consumption is not large. Leading overseas producers are USA, Canada, and Japan.

No Australian production of tellurium has been recorded since 1964, when output was 1.6 tonnes. The principal source of the metal is as a by-product of copper and lead refining. Small quantities are recovered from flue gases and dusts produced during the smelting of copper, lead, and bismuth ores, and during the roasting of tellurium-rich gold ores, and of some pyrite ores for the production of sulphuric acid.

Tellurium is chiefly 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)

In the past there was a small annual production of concentrates of bismuth as a by-product of tin and tungsten mining in the Northern Territory and Western Australia. In 1967, the Juno gold mine at Tennant Creek was responsible for the first Australian production since 1962. Production at Tennant Creek since then has expanded considerably with the production of bismuth concentrates from gold ores at the Peko and Warrego mines. The highest production, so far recorded was in 1979. The bismuth occurs with copper and gold, and much of the bismuth reports in copper-bismuth flue dust, a by-product of copper smelting. Research is continuing into methods of processing bismuth concentrates to bismuth bullion containing about 90 percent bismuth metal. Imports of bismuth metal totalled 13 479 kg in 1979, having ranged between 5000 and 22 000 kg in the period 1970-76. Present uses of bismuth are for alloys with precise melting points and for the production of salts used in the pharmaceutical and chemical industries. The use of bismuth as a metallurgical additive to aid the casting of iron and improve the machinability of aluminium and steel has increased in recent years. The continued strength of this market will depend on production in the ferrous and aluminium industries.

Magnesium (Mg) and calcium (Ca)

These are derived from dolomite ($(Mg,Ca)CO_3$) and limestone (essentially $CaCO_3$), of which Australia has an abundance. Elsewhere in the world, magnesium is produced from sea water; however, there is no production of magnesium in Australia. Magnesium is well known as a light metal, being only two-thirds the weight of aluminium. Suitably alloyed to increase its strength, it has been used increasingly in the aircraft and allied industries. Calcium is

50

a soft metal, of little use alone, but effective as a hardener of lead. Neither metal is produced in Australia, although magnesium was smelted from magnesite ($MgCO_3$) in limited amounts at Newcastle during the war. Australian resources for production are ample.

Mercury (Hg)

Australian reserves of mercury are negligible. Mercury was produced early in 1967 for the first time in Australia since 1945. In 1977, 50 kg of mercury metal was produced as a by-product during refining of Rosebery lead-zinc ores at Risdon. The mercury is recovered initially as an HgS slime containing about 2% Hg; this is a preventative measure against possible pollution of the Derwent River by refinery effluent. No production has been recorded since 1977.

In USA, electrical apparatus accounted for 50 percent of mercury usage; use in electrolytic preparation of chlorine and caustic soda, mildew-proofing paint, and industrial and control instruments accounted for most of the remainder.

Imports of mercury in 1979 were 47 990 kg; the bulk of imports was supplied by Japan (38 percent), China (36 percent), and Spain (24 percent). World production during 1979 was some 6.6 million kg. World consumption of mercury continued to decline in 1979 because of pollution fears, and demand for mercury is expected to increase at an annual rate of less than 1 percent throughout 1981.

Silver (Ag)

The main uses of silver are in photography and in electrical and electronic products. The price of silver has been rising for some time, and the metal, from having traditionally been a by-product, must now, at the present price of $500/kg, be said to have assumed co-product status. Most of the silver produced in Australia is a co-product of lead mining, but some is also a co-product of zinc, copper, and gold mining. Mine production in 1979 was 832 210 kg, most of which was in lead-zinc ore. Silver refined in Australia in 1979 was 320 370 kg and almost all the rest of the silver mine production was exported in base-metal concentrates, or lead bullion.

Indium (In)

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

Cobalt (Co)

Cobalt is a by-product of the Australian nickel industry and also of the production of zinc. It has a variety of uses which include high-temperature alloys, high-speed steels, and magnetic materials.

In 1979, mine production of cobalt totalled 3046 tonnes, of which 2202 tonnes were contained in lateritic nickel ore mined at Greenvale in Queensland, 762 tonnes in nickel concentrates produced in Western Australia, and 82 tonnes in zinc concentrates from Broken Hill. However, only a small proportion of cobalt produced in mine products is recovered in Australia. The zinc refinery at Risdon, Tas., which continues to be the major supplier of cobalt for Australian industry, produced 21 tonnes of cobalt in cobalt oxide from zinc concentrates in 1979. Nickel-cobalt sulphide products are produced at the nickel refinery at Kwinana and the Yabulu refinery near Townsville. In 1979 the cobalt content of materials from both these sources was 1562 tonnes, but these products will be exported rather than further refined in Australia in the immediate future. These by-products would make Australia self-sufficient in cobalt if suitably refined; in the meantime a large part of our relatively small requirements is imported in the form of metal and compounds, mainly from Zaire (the world's principal producer), Canada, Morocco, and Zambia. The USA is an alternative source from which imports are also obtained.

Cadmium (Cd)

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

In Australia, cadmium is produced solely as a by-product of lead-zinc-silver mining. Production of refined cadmium in 1979 was 804 tonnes of metal; 524 tonnes came from Risdon, 250 tonnes from Cockle Creek, and 30 tonnes from Port Pirie. Mount Isa produces minor quantities of cadmium-thallium sponge which is exported. Estimated domestic sales in 1979 were about 260 tonnes 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)

Annual production of gold, once steady at above 1 million troy ounces (32 150 kg) has been falling slowly for a number of years. In 1970, reflecting the difficulties confronting the gold mining industry, mainly resulting from fixed prices, production fell to 17 600 kg. However, rising gold prices in 1971 and 1972 temporarily reversed the trend and production rose to 23 500 kg in 1972, but then declined in the mid-1970s to about 15 000 kg annually. In 1979, production was 18 566 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 gold mines accounts for roughly 80 percent of Australian production. Of this, 80 percent in turn came from Western Australia in 1979. In terms of total 1979 production, however, 62 percent came from Western Australia, 9 percent from Tasmania, 3 percent from Queensland, with small contributions from New South Wales and Victoria. The remaining 25 percent came from the Northern Territory, mainly from Peko-Wallsend's mines at Tennant Creek.

Australia imports less than 1000 kg of gold annually, mostly as unrefined bullion, and exports total about 10 000 kg of refined gold, and so, despite decreased production in recent years, it remains a net exporter of gold.

Production is expected to decrease slowly in the future. The price of gold was US$195/oz at the end of 1974 but by the end of August 1976 it had fallen to US$103/oz. From this low point it recovered slowly and with the continuing weakness of the US dollar rose steadily in 1978, averaging over US$190 for the year, after reaching a maximum of US$242.60 on October 31. The price has since continued to rise and in late 1980 was about US$600/troy ounce.

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, and in the petroleum, glass and automotive industries. There has been a small erratic 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 has been recorded since 1968. A small amount is commonly recovered each year as a by-product of gold refining at Port Kembla. Platinum is now recovered from nickel co-products produced at the Kwinana nickel refinery. In 1979, production from this source was 292 kg of platinum-group metals.

Imports in 1979 were valued at $3.89 million and exports were valued at $1.0 million. The pattern of world production is stable, with South Africa, USSR, and Canada together accounting for over 99 percent 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.

Many countries deal extensively in the secondary trade of the platinum-group metals; in 1979, e.g., Australia imported 3892 kg, mostly from USA and UK (re-exports from those countries) and re-exported 339 kg, mainly to Hong Kong, New Zealand and UK.

US demand can be expected to increase in the 1980s as a result of the passage of the Clean Air Act by Congress in mid-1977. In order to meet the requirements of the Act, automotive manufacturers will need to use larger exhaust gas catalysers containing more platinum than has been used in the past.

NON-METALS

Abrasives

Australia is deficient in resources of natural hard abrasives, such as diamond (C), corundum (Al_2O_3) and emery (an impure variety of corundum containing varying amounts of iron oxides). Production of all these is negligible. Small amounts of industrial diamonds were once obtained as a by-product of gold dredging in the Macquarie River, NSW, but today the total requirement is imported; imports totalled 1 139 174 metric carats in 1979, but a considerable amount (194 232 carats) was re-exported. Zaire is the world's major producer, followed by USSR and other African countries. Currently there is a boom in diamond exploration in Australia. Many companies are engaged in diamond exploration particularly in the northwest of Western Australia, as well as in the southeast of the continent. The interest in diamond exploration has followed discoveries in 1978 in the Kimberly District by a consortium led by CRA Ltd. Major prospects under investigation by the consortium include Ellendale, Fitzroy and Argyle near Kununurra. Exploration on diamond leases by the consortium in 1979 totalled $8.4 million.

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 2000-3000 tonnes/year. Zimbabwe is the world's leading producer of corundum followed by USSR and South Africa. Turkey is easily the largest producer of emery.

Part of our requirement of garnet is obtained as a by-product of mining mineral sands along the eastern coast, as well as from sands near Port Gregory, WA. A production of 729 tonnes was recorded from these sources in 1979. The bulk of domestic requirements is met by imports, mainly from USA.

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

Arsenic (As)

Arsenic is mainly recovered as a by-product of copper and gold mining and the principal world producers are USSR, Sweden, Mexico, and France. Arsenic is used in insecticides, sheep dips, weed killers, wood preservatives, and in glasses and enamels. In 1975, Copper Refineries Pty Ltd at Townsville started producing copper arsenite, for wood preservative, at the rate of 100-200 tonnes/year. This is 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 tonnes 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 Australian requirements of arsenic are imported. A total of 936 tonnes of arsenic trioxide was imported in 1979.

A considerable amount was at one time obtained as a by-product from gold mining at Wiluna, WA, and a number of other Australian sources are known but 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 consumption of asbestos are collected in Australia, but more than 60 percent is known to be used in the manufacture of asbestos cement products.

Australia has large resources of blue asbestos (crocidolite) in the Hamersley Range, WA. Deposits of crocidolite near Wittenoom were worked, mainly for export, until 1966 when production stopped because of rising costs. There are few known deposits of amosite or of white asbestos (chrysotile) in Australia. However, a chrysotile deposit at Woodsreef near Barraba, NSW, which contains demonstrated reserves of 38 Mt of fibre-bearing rock, was brought into production in January 1972; output in 1979 was 79 721 tonnes of fibre (exports were 54 041 tonnes). A small quantity of chrysotile asbestos has also been produced at Baryulgil, NSW. Exploration in the Baryulgil area reportedly has indicated considerable reserves. The Woodsreef product is dominantly short to medium fibre and, although this satisfies local demand and provides exports to Japan, imports of longer-fibre chrysotile and of amosite remain significant. Imports in 1979 were 16 683 tonnes of chrysotile, 5205 tonnes of amosite, and 1054 tonnes of other varieties, mainly chrysotile fines. Canada supplied 71 percent and South Africa 24 percent of asbestos fibre imports.

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 of barite in 1979 was 94 066 tonnes. Most production (48 581 tonnes) was from Dorisvale, about 100 km west of Katherine, in the Northern Territory. However, production from Dorisvale, which began late in 1978, was suspended in November 1979 because of mining problems and to allow for a reappraisal of reserves. The North Pole barite deposit in Western Australia, 110 km east of Port Hedland, is also an important source of barite; production from this deposit started in 1975. The company exploiting this deposit, Dresser Products Australia Pty Ltd, interrupted mine production in 1978 to install a jig plant and otherwise upgrade productive capacity of the mine to about 80 000 tonnes/year. Production in 1979 was 34 658 tonnes. The company also operates a 50 000 tonnes/year mill in Port Hedland and is well placed to meet any future drilling-mud requirements of the Northwest Shelf. Dresser is likely to become an important exporter. Production from South Australia (9635 tonnes in 1979) was mainly from the central part of the Flinders Ranges but some is from Olary and Truro. Minor occurrences of barite are known in every State in Australia but of all such occurrences only those at Trunkey Creek, NSW, have, in recent years, produced small amounts consistently. Although about 75 percent of barite production worldwide 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 is also used in special concretes in hospitals and nuclear reactors for shielding purposes. Barite is also used for manufacturing a variety of barium chemicals although Australia has no such industry. Australia produces mainly drilling-grade and some industrial-grade barite; it is both an exporter of barite (mainly drilling-grade) and importer (mainly lump industrial-grade). Consumption of barite in Australia in 1979 was estimated by BMR as 18 000 tonnes.

Australia also imports various barium chemicals; the main ones (and 1979 imports) are: precipitated barium carbonate (910 tonnes), precipitated barium sulphate (blanc fixe, 389 tonnes), lithopone (barium sulphate and zinc sulphate, 96 tonnes) and barium chloride (236 tonnes). The barite equivalent of these chemicals, not included in BMR's consumption estimate of barite, is about 1800 tonnes.

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, and as the commercial viability of deposits of minerals of low unit value is mainly influenced by transport costs, domestic requirements will continue to be partly met by imports.

Bentonite and fuller's earth

Bentonite is a variety of clay that swells greatly in water and is used mainly to thicken oil-well drilling muds. Fuller's earth is a clay, that, because of its absorbent properties, is used in decolorising and purifying oils and greases. Recent Australian demand for bentonite has reflected the decline in petroleum drilling in the early 1970s, although there is an increasing demand in iron ore pelletisation and in moulding sands. Local production of bentonite in 1979 was from Queensland (1806 tonnes), New South Wales (14 000 tonnes), and

Victoria (820 tonnes), and imports totalled 57 241 tonnes; no fuller's earth was produced in 1979, compared with 68 tonnes in 1978. Deposits of bentonite in various States are being tested, and it is possible that Australian production may rise substantially in the future, although domestic freight rates present restraints to exploitation of new deposits. USA and Italy are the main world producers of high-quality bentonite, which is in heavy demand for drilling muds.

Diatomite

There are many small deposits of diatomite in Australia and small-scale production has been almost continuous since 1896; production in 1979 was 3592 tonnes and came from the Toowoomba Mining District, Qld, from Coonabarabran, NSW, and Lillicur, Vic.

Apparent consumption of diatomite in Australia in 1979 was 16 800 tonnes 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 of lower quality than imported material and is 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 essentially entirely of felspar and thus of 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 for the potash varieties, and the Olary District, SA for the potash-soda varieties. Production in 1979 was 3869 tonnes. This could be expanded almost at will, but consumption has declined owing to the greater suitability of nepheline syenite - which is not produced in Australia - for some applications.

Fluorite

The mineral fluorite, also known as fluorspar, is naturally occurring calcium fluoride (CaF_2). There has not been any production of the mineral in Australia since 1974 when Leighton Mining NL closed its small mine near Walwa, Vic., for economic reasons. Historically, fluorspar production in Australia has been on a small scale; in the previous fifty years only about 50 000 tonnes has been 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 95% CaF_2; and metallurgical grade - to contain not less than 80% CaF_2.

Apparent consumption of fluorspar (all grades) in Australia in 1979 was 27 000 tonnes. The steel industry is the largest consumer of fluorspar and The Broken Hill Pty Co. Ltd used about 14 600 tonnes of metallurgical-grade material in 1979, as a metallurgical flux for removing impurities in manufacturing steel. The balance of 12 400 tonnes represents mostly acid-grade material used mainly in production of anhydrous hydrofluoric acid (HF). There are two HF plants in Australia, at Newcastle and Camellia, 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 affect of fluorocarbons on the earth's ozone layer has 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 its fluorspar requirements, 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 1978-79 the total f.o.b. value of imports of fluorochemicals was $11.0 million. Because fluorspar is the major source of fluorine, resources are measured in tonnes of contained fluorine. Of total Australian identified resources of fluorine of 65.23 Mt, only 3.29 Mt occurs in fluorite deposits; by far the greatest portion of identified resources is contained in the fluorapatite ($Ca_5(PO_4)_3F$) that is the essential component of Australia's resources of phosphate rock. All known fluorite deposits are classified as submarginal and none are 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 possible resources have not been fully investigated. All our requirements are met by imports, which amounted to 1858 tonnes in 1979 (mainly from China, Korea, and Sri Lanka), plus 1623 tonnes of artificial graphite, mainly from Canada, Federal Republic of Germany, Japan, UK, and USA.

Limestone, dolomite, and magnesite

These have been referred to earlier in connection with the metals magnesium and calcium. Resources are very large and production could be increased indefinitely. Limestone is mined in Australia for use mainly in the manufacture of cement, as well as for metallurgical, chemical, agricultural, and other purposes. In 1979, limestone production was 11.45 Mt. Dolomite production for use as flux in the steel industry and in refractories was 746 832 tonnes.

Mica

Although Australia's resources are probably large, production, because of cheap overseas supplies, has been minor. In 1979, 310 tonnes of mica was produced. While the Commonwealth Mica Pool was operating during and after World War II, a series of small mines in the Harts Range in the Northern Territory produced most of our requirement. With the winding up of the Mica Pool in 1960, most mines stopped producing.

Imports in 1979 amounted to 628 tonnes, mainly from India, China, and South Africa. In the event of an emergency, Australia's domestic industry could probably be revived to meet requirements. Alternative sources of supply include Argentina, Brazil, and the Malagasy Republic.

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 an acute Australian shortage of high-quality quartz crystal, which has piezo-electric properties that are extremely 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 disclose any substantial deposits, and an intermittent search by industry in the years since has met with little success. Since 1952, when production was recorded from near Glen Innes, the only recorded production of quartz crystal has been from Mukinbudin, WA - 70 tonnes in 1974. Imports of quartzite and natural quartz amounted to 368 tonnes in 1978-79. Recent developments overseas in synthesising quartz crystals have eased pressure on the need to discover natural sources. Some 657 887 tonnes of high-grade silica sand were exported in 1978-79 mainly to Japan from deposits near Cape Flattery, north Queensland, and also from deposits near Perth, WA.

Sillimanite and kyanite (both Al_2SiO_5)

These related minerals are consumed chiefly in the manufacture of high-alumina refractory linings used in furnaces. Deposits of sillimanite are known in several parts of Australia, mostly in remote localities; currently the only production is from Mount Crawford, SA. Mineral sands in the Eneabba-Jurien Bay area of Western Australia are a large potential source of kyanite, although to date there has been no commercial recovery of the kyanite content. Australian production increased throughout the 1950s and early 1960s to meet increasing demands from industry, but after a peak of 3500 tonnes in 1963 it steadily declined. Production was 568 tonnes in 1979. Imports in 1979 under an item which included kyanite, sillimanite, andalusite, mullite, and dinas earth, totalled 3033 tonnes.

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

Talc, including steatite, pyrophyllite, etc.

The chief consuming industries are cosmetics, rubber, ceramics, and paint. Deposits are known in most of the States and, in recent years, Three Springs and Mount Seabrook in Western Australia, and Mount Fitton and Gumeracha in South Australia have been the chief producers. Production of talc in 1979 was a record 138 266 tonnes, of which 107 800 tonnes was exported. Imports, mainly of varieties not available in Australia, were 420 tonnes. Production of pyrophyllite from New South Wales totalled 19 209 tonnes, the bulk of which was from Pambula on the south coast. USA is the leading producer of talc and Japan is the major producer of pyrophyllite; Australian imports have come from mainland China, USA, and India as well as Italy and Norway.

Vermiculite

This mineral has the unusual property of expanding to many times its original volume when subjected to high temperatures and is used for fire and rot-proofing, as an insulator in electrical and heating equipment, in the manufacture of building plaster, and as a light-weight concrete aggregate. Western Australia is the only State in which vermiculite is produced.

There was no production in 1979; production in 1978 was 244 tonnes. A small amount is imported (2967 tonnes in 1979), South Africa being the main supplier (91 percent), and China (7 percent). USA and South Africa provide almost the entire western world production.

Salt & other sodium compounds

Salt (NaCl) production in Australia is all by solar evaporation, mainly of sea water but also of lake and underground (delta) 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 situated mainly in South Australia, Victoria, and Queensland.

Australia's salt industry expanded rapidly in the late 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 constructed and commissioned. In the mid-1970's export demand slackened and the industry was plagued by excess capacity. The Australian government set a minimum f.o.b. price of US$8.13/tonne for salt exports. This control was lifted a year later in March 1977. World demand and salt prices have since improved.

Australian salt production in 1979 was 5.22 Mt; production from Western Australia accounted for about 83 percent of this. The large export-oriented operations in Western Australia are located at Dampier and Lake McLeod (Dampier Salt Ltd), 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 600 000 tonnes/year of salt from Dry Creek, SA for manufacturing sodium carbonate and sodium hydroxide at its nearby alkali plant at Osborne; ICI also produces about 100 000 tonnes/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 Limited (Port Phillip Bay, Corio Bay, and Lake Tyrrell, all in Victoria), The Broken Hill Proprietary Company Limited (Whyalla, SA), Waratah Gypsum Pty Ltd (Lake MacDonnell, SA), Australian Salt Company Limited (Lake Bumbunga, SA), Ocean Salt Proprietary Limited (Price, SA), and Central Queensland Salt Industries Limited (Bajool, Qld).

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 for processing bauxite to alumina (Bayer process). 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 constrained by its limited capacity to consume by-product chlorine also. 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 are inadequately documented, 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 (see below).

Gypsum ($CaSO_4.2H_2O$)

The formation of gypsum usually requires semi-arid conditions. Although Australian occurrences are widespread, they are all within the region where annual rainfall is less than 500 mm. In 1979 Australia produced about 1.23 Mt tonnes of gypsum, about 64 percent of it from South Australia, where the main production centres are Lake MacDonnell and Kangaroo Island. Other important areas of production are Shark Bay, Lake Brown, and Yellowdine in Western Australia, Millawa, Nowingi, and Hattah in Victoria, and a smaller amount is produced from the Cobar Mining Division in New South Wales.

Australian exports of gypsum in 1979 totalled nearly 425 000 tonnes and were valued at \$3.33 million; 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 reserves total more than 760 Mt.

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 have been worked over the years and Australia undoubtedly has large resources of the iron oxide variety. In recent years, red and yellow ochres have been mined in the Ulverstone-Penguin area of northwest Tasmania and red ochre has been produced in the Weld Range area of Western Australia. Production of mineral pigments in 1979 totalled 222 tonnes. All production was red ochre from the Weld Range, W.A. Domestic consumption is small. Some 9367 tonnes of natural and synthetic iron oxides was imported in 1978-79.

Sulphur-bearing materials

Commercial deposits of elemental sulphur ('brimstone') and sulphur-bearing ('sour') natural gas are not known in Australia and in recent years 50-70 percent of demand has been met by imports, mainly from Canada and USA. Imports in 1979 of 436 000 tonnes were valued at $19.81 million f.o.b. Four oil companies recover sulphur from the refining of imported crude oil; 15 501 tonnes of sulphur was recovered from such refining operations in 1979. Although combined capacity of their six recovery plants is about 52 000 tonnes/year of elemental sulphur, actual production depends on the sulphur content of the refinery feedstock; this declined in the late 1960s when low-sulphur Bass Strait oil began replacing high-sulphur imported crude. However, Australia has large reserves and resources of sulphurous materials such as iron sulphide (pyrite), zinc sulphide (sphalerite), and lead sulphide (galena).

Sulphur is nearly all consumed in the form of sulphuric acid, and in 1979, 36 percent of Australian sulphuric acid production of 2.14 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 and Cobar, NSW), Port Pirie, SA, (lead concentrate from Broken Hill), and Risdon, Tas. (zinc concentrates from Broken Hill, Rosebery, Tas., and Mount Isa, Qld). A pyrite-based acid plant, at Burnie, Tasmania which used by-product pyrite from Mount Lyell and Rosebery in Tasmania, ceased production in August 1979, for economic reasons.

Three established acid producers have announced plans to construct new capacity, mostly brimstone-based, which, when completed by 1981, will lower the proportion of domestic acid production from indigenous sources to about 20 percent. Western Mining Corporation Ltd recovers sulphur as ammonium sulphate at the company's nickel refinery at Kwinana, WA.

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 situation, 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 for manufacturing phosphatic fertilisers, particularly single superphosphate. Of total Australian acid consumption in 1979 (2.10 Mt), 73 percent was in phosphatic fertilisers; 13 percent was in general chemicals, and 13 percent was in metallurgical applications.

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, tin plating and other electroplating, copper and zinc refining, and cleaning metal surfaces for soldering and welding. About 36 000 tonnes/year of elemental sulphur is consumed in Australia for other-than-acid uses, of which the main ones are in insecticides, fungicides, gunpowder, as a vulcanising agent in rubber, and for the manufacture of carbon disulphide.

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; potassium chloride, potassium sulphate, and sodium nitrate are exceptions to this, and minor quantities of crushed, locally produced phosphate rock are applied directly to the soil in South Australia.

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, as they are called, are normally applied mixed with the major fertilisers.

Phosphate rock: Phosphate rock is used almost entirely for the manufacture of superphosphate, production of which in 1979, in terms of single-superphosphate equivalent(9.6% P), was 3.98 Mt. Consumption of superphosphate in Australia has traditionally been subsidised by the Federal Government; presently the superphosphate bounty is $138/tonne of available P, equivalent to $12/tonne for single superphosphate.

Production of phosphate rock from northwest Queensland's large deposits, first discovered in 1966 by BH South Limited, commenced in April 1975. However, the project has been beset by flagging export markets, and Australian fertiliser manufacturers are reluctant to use the rock in its present (unbeneficiated) form because, with existing plant, it is more difficult and costly to grind and process than rock to which they are accustomed and for which existing plant has been designed. The unbeneficiated ('direct-shipping-grade') rock hitherto produced by BH South Ltd is harder to grind because of its higher chert content; it also liberates more fluorine during processing than rock from traditional sources. After incurring financial loses in three consecutive years, the company ceased mining operations in June 1978 and put the project on care-and-maintenance while continuing to study commercially viable methods of upgrading its product. In January 1980, after a series of share transactions, substantive ownerships and control of BH South passed to Western Mining Corporation Ltd (WMC). This company has since indicated that it intends to resume operations at Phosphate Hill, 68 km south of Duchess, at a reduced level (250 000 tonnes/year) as a means of re-establishing its presence in overseas and Australian markets. WMC is continuing to study ways of upgrading its product and Australian fertiliser manufacturers will also be directing future capital investment towards making plant more compatible with Queensland rock.

A small quantity of phosphate rock (7557 tonnes in 1979) is also produced in South Australia, but the material is not suitable for superphosphate manufacture because of its high aluminium and iron content; after crushing, this material is applied directly to the soil by local users.

Australia's requirements for phosphate rock have traditionally been imported from Nauru and Ocean Island (now called Kiribati) in the Pacific Ocean and Christmas Island in the Indian Ocean. Production from Kiribati ended November 1979 because reserves are now depleted. The Christmas Island deposits are owned jointly by Australia and New Zealand, and phosphate mining is carried out by the Christmas Island Phosphate Commission (CIPC) on behalf of the two Governments. Reserves here, at current rock prices and rate of extraction (1.4 Mt/year), are sufficient for about 7 years. Mining of the Nauru deposits was managed by the British Phosphate Commissioners (BPC), on behalf of the Australian, New Zealand, and British Governments, to 30 June 1967 when the operation was purchased by Nauru. After the formation of the Republic of Nauru on 31 January 1968, the Nauru Phosphate Commission was formed to manage the industry and on 1 July 1970, after a transition period, became fully autonomous.

Imports of phosphate rock in 1979 totalled 2.37 Mt and were valued at $85.14 million, f.o.b.

Australia's identified resources of phosphate rock are substantial: paramarginal resources are assessed as 2770 Mt of rock of average grade 7.39% P, and additional identified subeconomic resources are assessed as 2529 Mt of rock of average grade 5.59% P.

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 imports all its requirements, mainly from Canada and USA. In 1979 Australia imported about 160 000 tonnes of potassium chloride and about 9000 tonnes of potassium sulphate; the total value of imports including 2562 tonnes of other potassic fertilisers, was $12.10 million, f.o.b.

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 have, as a wartime measure, been exploited as a source of potassic fertiliser. At the end of the Second World War, the Western Australian Government sponsored attempts to produce commercial-grade potash from an estimated 12 Mt of alumitic

67

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 tonnes of potassic fertiliser from about 175 000 tonnes of alunite. Small amounts of alunite have also been produced from Bulahdelah, NSW; production from here stopped in 1952 after about 71 000 tonnes had beenproduced in the previous 60 years.

In November 1973 Texada Mines Pty Ltd commissioned plant to produce langbeinite ($K_2Mg_2(SO_4)_3$) from the residual brine liquor of its salt-producing operation (sodium chloride) at Lake McLeod, 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 tonnes of material, produced and stockpiled during progressive commissioning of the plant, was sold overseas in 1976 after BHP bought a controlling interest in the company. The controlling interest of the Lake McLeod operation has since passed to CRA Limited.

Nitrates: Australia has no known deposits of nitrates. However, many important nitrogenous compounds are manufactured in Australia, mainly from indigenous material; minor imports supplement requirements. The starting point for manufacturing nitrogenous compounds is ammonia, which can be produced or recovered from various sources including natural gas, refinery gas, coke-oven gas, air, and imported naphtha. The Broken Hill Proprietary Company Limited produces about 70 000 tonnes/year ammonium sulphate from ammonia recovered from coke-oven gas at the company's steelworks at Newcastle and Port Kembla, NSW and Whyalla, SA. Consolidated Fertilizers Limited (at Gibson Island, Qld) and Western Mining Corporation Limited (at Kwinana, WA) manufacture ammonia from natural gas; Kwinana Nitrogen Company Pty Ltd (at Kwinana, WA) makes ammonia from refinery gas; Eastern Nitrogen Limited (at Newcastle, NSW) and Queensland Nickel Pty Ltd (at Yabulu, Qld) manufacture ammonia from imported naphtha; Electrolytic Zinc Company of Australasia Limited (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 type 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 estimates the nitrogen content of nitrogenous fertilisers produced in Australia

68

in 1977-78 (the most recent statistics available) as 215 100 tonnes; the nitrogen content of imports of various nitrogenous fertilisers in the same period is estimated by BMR as 8600 tonnes.

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/tonne of contained N to consumers of nitrogenous fertiliser; the steady increase of consumption is partly due to the use of nitrogen in new applications, especially wheat, other cereals, and pasture. However in 1975, the Industries Assistance Commission (IAC) recommended that the subsidy be phased out over a period of three years. After deferring its decision in 1976, the Government reduced the subsidy to $60/tonne of contained N from 1 January 1977. A further reduction in 1978 was also deferred, but from 1 January 1979 the subsidy was reduced to $40/tonne of contained N, and from 1 January 1980 to $20/tonne contained N.

THE ROLE OF GOVERNMENT IN ASSISTING MINERAL EXPLORATION AND DEVELOPMENT

The Division of National Mapping in the Department of National Development and Energy provides a focus for the various Government organisations engaged in mapping. Overall coordination of the topographic mapping program, both Commonwealth and State, is provided by the National Mapping Council, consisting of the Director of National Mapping (Chairman), the Director of Military Survey, the Commonwealth surveyor General, the Hydrographer RAN, the Directors of Mapping in New South Wales and Tasmania, and the Surveyors General in the other States and the Northern Territory. There is complete interchange of mapping data between members of the National Mapping Council, both Commonwealth and State.

The Commonwealth undertakes all topographic mapping within its own territories and is active in most States; the Commonwealth mapping organisations are the Division of National Mapping which has the primary responsibility, and the Royal Australian Survey corps, which does a substantial amount of work. The basic scale of topographic mapping is 1:100 000 with 20 m contours: over 1000 maps have been published. The whole of Australia is covered by 1:250 000 maps, but only about one third are contoured. The forty-seven maps covering Australia at the 1:1 million scale are kept up to date. Nearly 800 map areas at 1:100 000 scale have been covered with orthophoto maps, which look like mosaics of air photographs, but have distortions removed and are true to scale. Mapping at larger scales is produced by the Army and the States, but only for limited areas. Air photographs and Landsat imagery for the whole of Australia is available.

National Mapping also makes bathymetric maps of the continental shelf at 1:250 000, with a contour interval of 10 m. 55 maps have been published and 40 more surveyed.

National Mapping publishes thematic maps of interest to the minerals industry, notably "Energy Resources", "Coal Resources" and 'Minerals Other Than Fuels", updated annually; and the "Geology", "Mineral Deposits" and "Mineral Industry" maps in the Atlas of Australian Resources. A series of thirteen leaflets describing all Natmap's products is available on request from Natmap Sales, P.O. Box 31, Belconnen, A.C.T. 2616.

Both Commonwealth and State agencies undertake regional geological mapping. Programs are agreed upon in consultation between BMR and the State Geological Surveys, but the work, being an integral part of scientific research programs, is necessarily a good deal slower than that of topographic mapping. By now over 90 percent of the continent has been covered at 1:250 000 scale. Mapping of complex areas at 1:100 000 scale is now well advanced in several regions.

Regional geophysical surveys have been carried out mainly by BMR, and a great deal of work has been done using airborne equipment. The ultimate aim is to provide nation-wide coverage by gravity, magnetic, radiometric, and seismic measurements. BMR completed a reconnaissance marine geophysical survey of the Australian continental margin several years ago. Private companies and State Geological Surveys have also made an important contribution.

State governments assist mineral search by providing, under certain conditions, services such as assays and drilling and metallurgical test work.

Another important though indirect form of Commonwealth assistance is through taxation concessions. The object of these is to encourage exploration by making exploration costs recoverable, or to promote development by allowing the recovery of capital outlays either within a relatively short period, or over the estimated life of a mineral deposit.

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

- The income tax rate is 46 percent of taxable income.
- Petroleum exploration expenditure is deductible against assessible income from any source (previously it was deductible only against petroleum income).
- For other mineral exploration, other than for gold, there is an immediate deduction of mineral exploration expenditure incurred anywhere in Australia, against income from mining activities only.

70

- All capital expenditure at the mine site (except exploration expenditure, which is written off immediately as above) of both general mining and petroleum mining can now be written off on a reducing balance basis at the rate of 20 percent (that is the miner can write off each year 20 percent of the accumulated capital expenditure remaining after the previous year's assessment, so that after 5 years he will have written of 67 percent of the total). Previously the rate was 4 percent per year, so this is a considerable concession. In the case of a mine with an estimated life of 5 years or less the miner can write off the capital expenditure by annual instalments over the life of the mine.
- For capital expenditure away from the mine site (e.g. for transport facilities or for certain port facilities) the capital expenditure can be deducted over 10 years or 20 years at the option of the taxpayer.
- The 'investment allowance' for new items of equipment (which applies to all industries) is 20 percent of the value of almost all depreciable equipment installed before 1 July 1986.

Particular minerals have in the past been given specifically favourable taxation treatment in the form of a 20-percent exemption from tax, because it was felt that there was a national need to foster exploration for them; and gold mining as a special case has been free of income tax since 1924. The 20-percent exemption from tax for particular minerals was removed in 1973, but profits from gold mining are still tax free.

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

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

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

CONCLUDING REMARKS

Thus, it need hardly be said that the picture is a favourable one. With a few notable exceptions we can provide for all our mineral requirements and, in many cases, for an exportable surplus as well. One may confidently expect that with the passage of time most if not all deficiencies will be rectified. It is, in fact, difficult to think that if programs of vigorous exploration keep pace with the growing demands on our mineral deposits, important discoveries will not continue.

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 2. 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. For several reasons, published figures tend to be minimal and ultra-conservative. BMR is carrying out more realistic assessments and has completed and published first assessments of identified resources of black coal, beach-sand minerals, tin, iron ore, tungsten, and antimony; a detailed reassessment of tin resources and an assessment of chromium resources are under way and those for other minerals will follow. In Table 2 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 in the manufacturing industry.

72

TABLE 1. VALUE OF EXPORTS BY INDUSTRIAL GROUPS

	1975-76		1976-77		1977-78		1978-79		1979-80(a)	
	Value (f.o.b. $'M)	%	Value (f.o.b. $'M)	%	Value (f.o.b. $'M)	%	Value (f.o.b. $'M)	%	Value (f.o.b. $'M)	%
Industrial groups -										
Agriculture	2 104.5	22.6	2 137.2	18.8	2 055.2	17.2	1 858.0	13.4	3 923.6	21.7
Pastoral -										
Wool	961.9	10.3	1 477.4	13.0	1 183.1	9.9	1 433.6	10.6	1 532.6	8.5
Other	912.3	9.8	1 304.2	11.5	1 629.8	13.7	2 430.0	17.6	2 523.5	13.9
Dairy and farmyard	213.0	2.3	204.4	1.8	209.6	1.8	232.0	1.7	277.7	1.5
Mines and quarries(b)	2 777.7	29.9	3 421.0	30.1	3 607.4	30.3	3 888.3	28.5	4 502.1	24.9
Fisheries	83.4	0.9	143.8	1.3	152.8	1.3	212.2	1.5	254.9	1.4
Forestry	11.7	0.1	12.4	0.1	13.1	0.1	18.8	0.1	25.1	0.1
Total primary produce	7 064.4	75.9	8 700.3	76.4	8 851.0	74.2	10 072.9	73.4	13 039.5	72.0
Manufactures	1 945.9	20.9	2 368.4	20.8	2 680.1	22.5	3 200.5	23.4	4 177.3	23.1
Refined petroleum oils	158.7	1.7	200.3	1.8	232.1	1.9	286.5	2.1	384.1	2.1
Unclassified	133.7	1.4	112.4	1.0	159.0	1.3	144.3	1.1	514.0	2.8
Total Australian produce	9 302.6	100.0	11 381.5	100.0	11 922.0	100.0	13 704.2	100.0	18 114.9	100.0

(a) Preliminary. (b) Exports of gold are excluded for 1975-76.

TABLE 2. MINERALS IN AUSTRALIA, 1979: ORIGIN, SUPPLY, PROCESSING, ETC.

	Availability			Processing			
	Distribution	Identified resources	Current raw material imports	Level of processing	Distribution	Current imports	Possible disadvantages in emergency
Energy minerals							
Petroleum (a) Crude Oil	Wide but mainly Bass Strait	Medium	About 30% of requirement - crude and refined products	Full range of refinery products and petrochemicals	Well distributed	Some refinery products, heavy crudes	Major supplies offshore. Impor of heavy crudes
(b) Natural Gas	Wide, but some with long distances to markets	Large	-	Sales gas. LPG for export and home market. Etheline for petrochemicals.	Expanding. LNG export to commence 1985-86.	-	-
Uranium	Northern Australia, WA, SA	Large	-	U_3O_8 (yellow cake) radio-isotopes	Northern Australia, Sydney	Radio-isotopes	Reserves widespread but current plant only in Qld., NT.
Coal	Mainly Eastern Australia	Very large	Some high-quality anthracite	Coke, coal gas, char	Coke-Qld, NSW, SA, Char - Vic. WA	Petroleum coke	No chemical plants
Oil Shale	Eastern Australia	Large	-	-	-	-	-
Ferrous							
Iron ore	Well distributed	Very large	-	Ores and pellets, to steels and fabrications	Steel - well distributed	Ferroalloys, special steels	-
Nickel	WA, Qld	Very large	-	Concentrates, matte, metal, oxide, sulphide product	WA, Qld	Metal and alloys	Metal available but remote from most industrial centres
Chrome	WA minor NSW, Qld	Adequate metallurgical and chemical	Bulk of requirements	-	-	Ferrochrome	Largely dependent on imports.
Manganese	Groote Eylandt, NT	Large (metallurgical)	Battery-grade	Ferromanganese	Tasmania only	Some ferromanganese and metal	Main reserves i NT. No battery grade. No metal capacity.
Tungsten	King Island, Tas., and Qld. Minor-NSW, WA.	Adequate	-	Concentrates	-	Tungsten	Small tungsten carbide capacit (but could be increased)
Molybdenum	Minor-NSW, Qld, Tas.	Very small	Bulk of requirements	-	-	Ferromolybdenum, molybdic trioxide	No domestic capacity of acid and ferromolybdenum in emergency.
Non-ferrous							
Tin	Well distributed - mainly Tas.	Adequate	-	Concentrates and metal	Metal - Sydney only.	Minor	Major deposits not on mainland. Only one refinery
Lead	Well distributed - mainly eastern Australia	Large	-	Concentrates, bullion, and metal	Metal - NSW, SA	-	-

	Availability			Processing			
	Distribution	Identified resources	Current raw material imports	Level of processing	Distribution	Current imports	Possible disadvantages in emergency
Non-ferrous (continued)							
Zinc	Well distributed - mainly eastern Australia	Large	-	Concentrates, metal	Metal - Tas., NSW, SA	-	-
Copper	Well distributed - mainly eastern Australia	Adequate	-	Concentrates, blister, metal	Metal - Qld, NSW	-	-
Mineral sands							
Titanium	E and SW coasts	Adequate	-	Concentrates, upgraded ilmenite, pigments	Pigment - WA, Tas.	Any metal required	No metal capacity
Zirconium	E and SW coasts	Adequate	-	Concentrates	-	-	No metal or oxide capacity
Monazite	E and SW coasts	Adequate	-	Concentrates	Eastern Aust.	-	Could produce rare earths.
Light metals							
Aluminium	Northern and SW Australia	Very large	-	Alumina, metal	Metal - NSW, Vic., Tas.	Minor shapes	Major resources N. Aust. Alumin Qld. & WA remot from smelters
Magnesium	Well distributed (magnesite)	Adequate	About 60% magnesite	No metal produced	-	All metal	Metal can be produced as in World War II
Fertiliser/industrial minerals							
Phosphorus (phosphate rock)	NW Qld, NT	Very large	All requirements	-	Fertiliser made in all States	Some mixed fertilisers	Domestic resour ces only in NW Qld, NT.
Potassium	WA	Appear adequate	All requirements	-	Fertilisers all States	Some mixed fertilisers	Deposits remote from factories.
Sulphur	(Sulphides) well distributed	Elemental nil, sulphide large	50-70% of requirements	Acid plants	Well distributed	-	
Salt	Well distributed	Unlimited	-	Salt, sodium hydroxide, chlorine, sodium carbonate	Well distributed	Some chlorine, 70% caustic soda requirements.	

	Availability			Processing			
	Distribution	Identified resources	Current raw material imports	Level of processing	Distribution	Current imports	Possible disadvantages in emergency
<u>Minor metals</u>							
Vanadium	WA, Qld (oil shale)	Large	-	Vanadium pentoxide	-	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	Tas., WA, Qld	50% cobalt plus alloys	No metal or alloy capacity
Mercury	Eastern Australia	Small but uncertain	-	Metal (by-product)	Tas.	Almost all requirements	Very little normal production - could be increased
Mica	Central and Western Australia	Adequate	-	-	-	All grades	No current operation but could be produced
Cadmium	NSW, Tas, Qld	Adequate	-	Metal (by-product)	NSW, SA, Tas.	-	-
Antimony	NSW, Victoria	Adequate	Very small	Metal (by-product) contained in antimonial lead	SA	Metal plus oxides	No metal capacity
Beryllium	NSW, WA	Small but uncertain	-	No processing	-	Any metal required	No metal capacity