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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD 1979/14

MINERAL RESOURCES OF AUSTRALIA

1979

by

J. Ward and I. R. McLeod

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INTRODUCTION

This paper, designed for Industrial Mobilisation Courses in 1979, 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.

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, and the end still seems far from sight. Our growth as a nation has owed much in the past to the flow of population and capital which followed the early mineral discoveries. This flow reached a peak towards the end of the last century, then slackened for almost fifty years; it began again in the last two 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 surpassing wool as a mainstay of the economy at a time when rural industries in general were depressed. Statistics available do not indicate the real contribution of the mineral industry to G.D.P. but the value of exports of industrial groups within Australia, given in Table 1, shows the rising impact of the mineral industry on overseas funds as the largest single export earner in recent years. The contribution of mines and quarries in 1977-78, given as 30.1 percent of all exports, is in fact higher, because the industrial classification used in Table 1 allocates some exports by the smelting and refining sections of the industry to 'manufactures'. For example, if the value of alumina is added to mineral exports the contribution rises to 36.0 percent.

However, the mineral industry cannot be seen in perspective without identifying problems as well as achievements. The need for additional reserves of crude oil is urgent; the use of foreign capital in both exploration and development has eroded Australian equity in the industry; restricted domestic markets for processed products, amongst other factors, continue to place restraints on mineral processing; inflation and increase in domestic costs, relative to those overseas, have eroded our competitiveness and discouraged new developments; and the prosperity of the industry, inevitably based on exports although benefiting from long-term contracts, remains heavily dependent on the Japanese economy, which currently provides markets for 52 percent by value of our mineral exports. Indeed the slowing down of the Australian mineral industry since 1975, as a result of lower world metal prices and of checks to the economy of both USA and Japan in particular, serves as a salutary reminder of our vital concern with world economies and of our need to diversify our mineral trade as much as possible.

Reactions from Australian and foreign stock exchanges, the inevitable failure of some ill-equipped small mining companies, and other regrettable but spectacular events following 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 phenomenal rate of annual increase in production has been lowered but not reversed. The value of ex-mine production and of exports continued to rise in 1976, 1977, 1978 and on evidence to date will continue to rise in 1979. The level of exploration funds, certainly in real terms, declined in 1975 and 1976; it rose slightly in 1977 and appeared to be continuing to rise in 1978; a high rate of exploration is important if Australia is to be provided with the additional ore deposits required for continued development of the mineral industry in the 1980s, and is to be able to make proper assessments of its resources.

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

In the twenty years to 1973 both State and Commonwealth Governments encouraged private enterprise from both domestic and foreign sources to carry out detailed prospecting and development aided by governmental contributions through regional mapping and other fundamental scientific work and by financial assistance in some specific areas. In recent years, both State and Commonwealth Governments have become more concerned with the details and the timing of mineral development. The end of 1972 brought important changes in minerals policy under a 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 which were submitted to the Commonwealth Parliament in late 1973 to strengthen the Australian Industry Development Corporation (AIDC) and to establish a Petroleum and Minerals Authority.

In the event, these changes in policy, which included reduced taxation incentives, brought some confusion and indecision to the mineral industry because new guidelines were not clearly established although this was under way at the end of 1975 when however, the Labor Government was replaced by a new Liberal-National Country Party administration. The Labor proposals for revision of the AIDC and for the establishment of the Petroleum and Minerals Authority were never passed by the Senate, although the nucleus of a PMA did invest some $2.9 million in the Australian mineral industry up to late 1975. The new Liberal Government abolished the PMA and reorganised the Pipeline Authority.

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

On the other hand, the inevitable growing concern in environmental fields is accompanied by delays and additional costs in some mining 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 due to the attitude of industrial unions and to problems associated with aboriginal land rights and environmental considerations.

At the end of these notes reference is made to some of the policies followed in recent years with the intention of encouraging development or of conserving national resources. Attached also is a summary of ore reserves and of mineral processing in Australia as an indication of both resources and processing facilities. Overseas trade in minerals and mineral sufficiency are illustrated in the diagram showing values of imports and exports of minerals in 1977, which is attached at the end of the report. The table and diagram are perhaps more effective in illustrating the present situation than any amount of text can hope to be.

The minerals discussed are grouped under the following headings -

(a) Iron, manganese, chromium and other metals commonly used in the manufacture of steel;
(b) Base metals - copper, lead, zinc, and tin;
(c) Beach sand minerals - rutile, ilmenite, zircon;
(d) Other metals;

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(e) Non-metallic minerals;
(f) Fertiliser minerals;
(g) Fuel minerals - coal, uranium, and petroleum (i.e. oil and natural gas).

Mineral statistics given are those for 1977, the latest calendar year for which complete figures are available.

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

DEVELOPMENT OF THE MINERAL INDUSTRY

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

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

Early Settlement and Exploration

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

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

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

The first metalliferous mines did not open until the 1840s. Silver-lead ores were mined in 1841 near Adelaide in territory subsequently to become South Australia, and copper at Kapunda in the same general area in 1842. In the same decade but farther east in New South Wales the first pig iron was produced from bog iron ore deposits at Mittagong near Sydney, although the enterprise found great difficulty in competing with imported material and eventually ceased operation in the 1860s.

Establishment of the Mineral Industry

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

It was not long before new interest and expertise in prospecting arising from the succession of gold discoveries led to the discovery and exploitation of other metals; the start of tin mining near Inverell, New South Wales in 1871 and at Renison Bell, Tasmania in 1872 heralded very considerable tin production in eastern Australia, which in fact became the major world source of tin for nearly a decade in the late 1870s and early 1880s. Copper mining was rejuvenated by discoveries at Cobar, NSW, in the early 1870s and the finding of Mount Morgan in Queensland in 1882 and of Mount Lyell in Tasmania in 1885; although the latter two deposits were first mined for gold they provided large reserves of copper ore toward the close of the century. The mineral industry was further diversified with the discovery of the rich silver, lead, and zinc lodes at Broken Hill, New South Wales, in 1883, which, to the credit of the pioneers of that field, were developed to the stage of local smelting by 1885 and as feed to larger smelters at Port Pirie by 1889.

Up to this time successful mining had been restricted to eastern and southern Australia, despite attempts to discover payable gold in the Kimberley and Pilbara divisions of Western Australia and in areas east of Perth. However, discovery of payable alluvial gold near Coolgardie in 1893 and subsequently of the gold lodes of Kalgoorlie extended profitable mining to the western portion of the continent at a time when the economy in the east badly needed new outlets.

The Lean Years

The mining industry continued to prosper in the early years of the twentieth century, but fortune began to change and a general decline in both production and ore reserves of copper, gold, and tin continued at least until the 1950s, although gold production temporarily revived in the 1930s. During the lean years, significant new mineral discoveries were restricted to lead-zinc at Mount Isa in 1923 and scheelite on King Island in 1925. Only silver, lead, and zinc production and exports, based on Broken Hill in New South Wales and on Mount Isa in Queensland,

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

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

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

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

The Boom Years

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

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

It is interesting to note how technological progress has changed the pattern of mineral discovery in Australia since the thirties. Before the Second World War the discovery of most mineral deposits owed little to science but much to the keen eye, the luck, or the curiosity of prospectors, boundary riders, and other amateurs. Since the 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 provided processed aluminium and nickel for Australian industry. The long list of significant mineral insufficiencies of the late thirties has been spectacularly reduced to sulphur, asbestos, and industrial diamonds, although recent development of an asbestos deposit in New South Wales has significantly reduced our reliance on imported asbestos.

But perhaps the most notable changes brought about by the upsurge of the mineral industry concern overseas funds and the Australian economy as a whole. The value of exports of mineral primary products has risen from $69 million in 1950 to $4742 million in 1977, to provide currently about 40 percent of Australia's overseas earnings and to replace the agricultural and pastoral industries as Australia's largest export earners. The mineral industry produced in 1965 what was probably the first favourable balance of overseas mineral trade this century; this favourable balance has grown from $5 million in 1965 to $3826 million in 1977 and will undoubtedly continue to increase in the decade ahead.

Moreover, the rise of the mineral industry was timely, happening at a time when wool and most other rural industries were in difficulties, and doubtless saved Australia from currency devaluation and import restrictions in the late sixties. Reserves of iron ore, black coal, and bauxite, which supported about 68 percent of Australian mineral exports, are very large and, combined with long term contracts and rising demand for minerals throughout the world, promise continued major production and export.

However, upsurge of the mineral industry since the Second World War brought problems as well as achievements. The cost of exploration and development far exceeded the funds available in a country with a population not yet 14 million; overseas funds were sought and accepted in terms of risk capital for exploration and investment in mining operations, with inevitable erosion of Australian equity in both petroleum and mining industries. Moreover, since ore reserves are wasting assets, a continued flow of risk capital is required in the future to provide more reserves, particularly of crude oil if Australia's 72 percent self-sufficiency in oil in 1977 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 and nickel, have not kept pace with inflation. Restraints to mineral development were also increased by changes in taxation schedules and particularly by the repeal of provision for accelerated depreciation in the mineral industry although changes in 1976 and 1977 have provided more encouragement.

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

The late sixties brought growing awareness in Australia as elsewhere of environmental problems which inevitably questioned the disturbance of landscape, and levels of pollution which accompanied in varying degrees the operations of the mining and some other industries - the mining industry has so far taken the brunt of the attack; as a result the mining industry no longer operates with the degree of isolation from the rest of the community that 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 seventies in Australia may well have begun the transition of the mineral industry from the boom years into a fourth stage of development in which enthusiastic search and development gives place to consolidation and to more deliberate development, and in which attempts will be made to better relate the potential and problems of the mineral industry to overall community needs.

IRON AND FERROALLOYS

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

Iron and Steel: Production of iron ore for iron and steel-making in 1977 was about 96 million tonnes, an increase of 3 percent above the output in 1976. Production of raw steel in Australia decreased to 7.3 million tonnes in 1977, 6 percent below that in 1976; production of pig iron decreased by 9 percent to 6.8 million tonnes in 1977. Apart from a slight improvement in the June quarter, production of steel continued to decline in 1977 in response to depressed domestic and overseas demand. Output fell at all steelmaking centres. The largest decrease was at Port Kembla where No.1 open-hearth steelmaking shop was shut down.

A high proportion of iron and steel products continued to be exported in 1977; exports of crude steel including ingots, blocks, lumps, blooms billets and slabs decreased to 1 280 000 tonnes valued at $153 million compared with 1976 but despite depressed export demand were still at a comparatively high level compared with pre 1975 exports. Exports of crude steel plus rolled and shaped iron and steel products were valued at $456 million in 1977 and imports at $228 million. Production capacity for pig iron is surplus to domestic needs and exports were valued at $49 million in 1977.

Domestic iron and steel making absorbed 9.9 million tonnes of iron ore in 1977. The main sources were the Middleback Ranges in SA, 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 71 000 tonnes of ore from Koolyanobbing in 1977; 27 200 tonnes of iron oxide, mainly magnetite, was imported chiefly from Canada in 1977 for use as a heavy medium in the coal washing industry. In addition to the iron ore consumed in Australia, about 79 million tonnes of ore including 9 million tonnes of pellets was exported, slightly less than 81 million tonnes of ore including 9 million tonnes of pellets exported in 1976. Exports were principally from Western Australia; Tasmania continued to export pellets. Although reduced demand has resulted in a fall in the quantity of iron ore exported since 1974 the f.o.b. value of exports has increased to $952 million ($589 million in 1974) because of increased prices.

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

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

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

Deposits in Western Australia have since been vigorously tested and extremely large tonnages of high-grade ore have been demonstrated. Though the full extent is not yet known, a recent assessment by the Bureau of Mineral Resources has placed economic resources in the Hamersley Iron Province alone at around 15 300 million tonnes within total economic resources for Australia of 18 000 million tonnes. In other words, since 1959 our known resources have increased some 48-fold at least and all anxiety for adequate domestic supplies has been removed for many years to come.

However, not all the increase in reserves has come from the discovery of new deposits. Metallurgical research aimed at making possible the use of low-grade ores, of which there is an abundance in several States, has also contributed to the changed picture and may have a greater long range effect than is presently realised. Two producers in Western Australia are currently constructing major plant, scheduled for operation in 1979, which will be capable of upgrading low grade ores mined in conjunction with high grade ores.

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, has become 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 200 million dollars annually and has been running at more than a hundred million for several years. New major plant items commissioned since 1962 were a ferro-alloy plant and expansions at Bell Bay, Tasmania; an electrolytic tinning line, a high speed pickle line, a second hot-roll processing line, a new blast furnace and a basic oxygen steel-making plant at Port Kembla, New South Wales; a basic oxygen steel-making plant and associated rolling mill facilities, as well as a continuous steel casting plant, at Newcastle. At Whyalla a second blast furnace and an integrated steel plant opened in 1965, and an iron ore pelletizing plant was commissioned in 1968. At Kwinana, the first stages of an iron and steel complex were constructed, and a cold rolling plant was completed at Unanderra, where a vacuum degassing plant also commenced operations.

Although some optimism was held for a recovery in steel demand in USA and Europe early in the year demand remained depressed and steel continued to be in oversupply during 1977.

Demand for steel improved in 1978. However non-Communist world consumption was estimated by the International Iron and Steel Institute to have remained below peak consumption of 491 million tonnes in 1973. World production increased by 6 percent to a record 712.5 million tonnes.

Manganese is one of the key metals in the manufacture of steel its chief use being as a de-oxidiser and a de-sulphuriser in the plant process; adequate supplies of its ores are essential for the long range security of the steel industry. Current usage requires about 30 lb of manganese dioxide for every tonne of steel produced. It is also a hardening constituent in many grades of steel; and high-quality manganese dioxide is used in the manufacture of dry cell batteries. In 1977, 320 000 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 the Bureau of Mineral Resources at Groote Eylandt, in the Gulf of Carpentaria, where BHP have now established an open cut mine and treatment plant. Shipments of ore from Groote Eylandt have increased to supply most of Bell Bay's ferromanganese requirements, plus an export surplus. This deposit can supply all of Australia's requirements for metallurgical grade ore for a long period to come; however, we have no supplies of battery-grade ore and continue to use imported ore at the rate of about 1400 tonnes per year. In addition increasing quantities of electrolytic manganese dioxide (1070 tonnes in 1976-77) are being imported from Japan and USA for battery manufacture.

Australian production of manganese ore in 1977 was about 1.4 million tonnes. Exports normally exceed 1.0 million tonnes annually, mainly to Japan and European markets. Imports other than battery grade ores have shown a marked decline from 1965 and were about 10 tonnes of ore in 1977. Australia's production of high carbon ferromanganese now satisfies local demand, but imports of other grades including powder totalled 3940 tonnes in 1977. 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.

<u>Nickel:</u> Following the initial discovery of nickel ore at Kambalda in 1966 other companies made important finds and by 1973 eight nickel mining operations were in production. However by the end of 1978 three of these had ceased operations and one new mine had started producing nickel ore. Western Mining Corporation remains the largest producer of nickel ore from its group of mines at Kambalda where proved and probable ore reserves at June 1978 were estimated to be 21.29 million tonnes averaging 3.24 % Ni. In 1977 WMC produced a total of 37 783 tonnes of nickel in concentrates. Nickel contained in ore produced at the Nepean mine, owned by Metals Exploration Limited, and from the Carr Boyd Rocks and Scotia mines, then owned by Great Boulder Mines Ltd, are included in the WMC figure.

The Greenvale lateritic mine (Metals Exploration Ltd - Freeport Minerals Co) in northern Queensland produced almost 2 million tonnes of ore from which 19 046 tonnes of nickel was recovered as sintered nickel oxide. Proved ore reserves at this mine are slightly less than 40 million tonnes at an average grade of 1.59% Ni.

Windarra Nickel Mines Pty Ltd (WMC 50% - Shell Company of Australia Ltd 50%) produced 12 114 tonnes of nickel in concentrate in 1977. The mine has been on a care-and-maintenance basis since early in 1978 because low nickel prices made the operation uneconomic.

The Redross mine (Anaconda Co. Conzinc Rio Tinto of Australia Ltd) produced 3227 tonnes of nickel in concentrate in 1977 but the mine ceased operations in 1978 because of lack of ore.

Spargoville Location 3(Selcast Exploration Ltd) produced 3111 tonnes of nickel in concentrate during 1977. This mine is expected to stop production early in 1979 because of lack of ore.

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One new mine, the Agnew project, operated by Agnew Nickel Co Pty Ltd which is owned 60 percent by Western Selcast Pty Ltd and 40 percent by 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 the world wide recession in the nickel industry initial production is at the rate of 10 000 tonnes/year of nickel in concentrate. Proven ore reserves at the mine are 45 million tonnes averaging 2.2 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. The large lateritic deposit at Wingellina in Western Australia near the northern section of the South Australian border and the large disseminated sulphide deposit at Mount Keith, south of Wiluna, require more favourable economic conditions before development and production can start. Both of these deposits are in isolated areas and difficulties facing companies which may develop the orebodies include the cost of providing water both for human consumption and industrial use, the high cost of providing the necessary infrastructure and of either upgrading present transport systems or providing new systems.

Production of nickel concentrates commenced in June 1967 at Kambalda and output for that year was 2060 tonnes of contained nickel. In 1977 Australian mine production of nickel was 85 868 tonnes. Australia is now the third largest producer of nickel in the non-Communist world. In 1977 about 95 percent of the nickel mined was domestically processed to either metallic nickel, high grade nickel matte or sintered nickel oxide. The nickel refinery at Kwinana near Fremantle commenced production in 1970 with an output of 15 000 tonnes/year of metallic nickel. Output in 1977 was about 17 000 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 18 000 tonnes/year of nickel in matte, but this has since been increased to about 35 000 tonnes/year and at the end of 1978 the work entailed in doubling this capacity was about completed.

Tungsten: Since tungsten became of commercial importance about 1900, Australia has been an important producer of its ores - wolfram and scheelite - but the scale of production has varied 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. Wolfram comes mainly from Avoca, Tasmania, where Aberfoyle and Storey's Creek mines have been the principal producers; and from mount Carbine in northern Queensland where Queensland Wolfram Pty Ltd is operating. A major deposit of scheelite is mined on King Island, Bass Strait, where known reserves have increased from 1.47 to 6.7 million tonnes, averaging 0.8% tungstic oxide.

At the start of 1977 the London Metal Bulletin quotation for standard-grade wolframite concentrates was US$142-147.50/mtu and had risen to US$166-176.50 by the end of December. The average of the LMB quotations for the year was US$170.67/mtu, 49 percent more than the average for 1976. In 1978, members of the Primary Tungsten Association (PTA) decided to introduce a new pricing system - the International Tungsten Indicator (ITI) The PTA believes that the ITI will more accurately reflect the market, and thus help to stabilise the price.

Australian production in 1977 (expressed as concentrates of 65% WO_3 content) was 4574 tonnes, and recent enhanced prospects on King Island and of Queensland Wolfram at Mt Carbine promise higher production of scheelite in the future even if operations are stopped at the high cost mines in the Avoca area. The scheelite produced at King Island contains sufficient MoS_2 to attract a penalty. A plant to produce artificial scheelite has been constructed there, and the resulting by-product MoS_2 will be sold. The total domestic consumption of WO_3 has never

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exceeded 100 tonnes per annum, its main use being in the manufacture of tungsten-carbide tipped tools.

Molybdenum: Before 1920 substantial quantities of molybdenite were produced in Australia, but for many years production has been small. No domestic production of commercial-grade molybdenite concentrates was recorded in 1977. Imports of molybdenum ore and concentrates more than trebled in 1977 to 309 tonnes, imports of ferromolybdenum more than doubled to 205 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, of which development to any depth is costly. One exception is at Yetholme, New South Wales, where some 800 tonnes of molybdenite lies at shallow depth beneath a comparatively thin overburden. During World War II the Commonwealth sponsored exploration for new deposits, but results were generally not encouraging. Production from Mareeba, Queensland, is expected to re-start in 1979, and a deposit at Mount Mulgine, Western Australia, is under investigation. Recovery of molybdenum as a by-product from treatment of scheelite at King Island, beginning in 1978, could supply part of our demand.

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

Chromium: Chromite, the ore which yields the metal chromium, has two uses in the steel industry; as an ingredient in the production of alloy steel, and as a chemically inert furnace lining. Its other main use is in the manufacture of chemicals. Australian annual consumption of chromite runs at about 8000 tonnes, all of which is normally imported. In 1977, 10 750 tonnes of chromite was imported, mainly from South Africa and the Philippines. Imports of ferrochrome, mainly from South Africa, increased to 12 480 tonnes in 1977.

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The largest known Australian deposit of chromite is at Coobina, in the Ophthalmia Range, Western Australia. The only recorded production was between 1952 and 1957 when approximately 14 500 tonnes of ore was produced. Investigations in the 1970s indicated that the deposit, which varies in grade and is structurally complex, cannot support an economic mining operation despite the nearby development of transport and processing facilities for iron ore at Newman. Minor production of chromite was recorded at Barnes Hill, Tasmania in 1978. Previously the most recent production of chromite in Australia was 138 tonnes from Licola, Victoria, in 1967, and 86 tonnes in 1968.

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

Vanadium. This metal, used in both ferrous and non-ferrous alloys, and in the chemical industry, is a common constituent of minerals, though there are relatively few deposits mined. None has been produced in Australia and local consumption is negligible, but recent exploration has indicated possible economic hard-rock deposits in Western Australia, and potential supplies as a by-product of petroleum recovery from oil shales in northwestern Queensland. Agnew Clough Ltd commenced work on construction of mine access roads to its Coates Siding deposit in mid 1978. Vanadium pentoxide production is planned to commence in late 1979 at an initial rate of 1130 tonnes/year. Overseas sources of supply, if required, would be the United States, South Africa, Finland, and Southwest Africa. World production in 1977 was about 28 300 tonnes.

BASE METALS

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

Since the discovery, in 1883, and the development of the Broken Hill silver-lead-zinc orebody, perhaps the richest in the world, Australia has been a major producer of lead and zinc ores; and her already dominant position was reinforced by the discovery and exploitation of Mount Isa in the years following 1923. It is interesting to note that Australian metal mining began with silver-lead in South Australia in 1841. We have been amongst the world's leading producers of lead for a number of years past and in 1977 with a production of 432 204 tonnes we ranked as the third largest producer in the world behind USA and USSR. Our known resources are sufficient to allow us to continue as a major exporting country for several decades to come.

Mine production has run uniformly high in recent years, after being below capacity in 1970-71, when it was affected by an international arrangement un which a substantial part of Australian production was voluntarily curtailed. Although output in 1977 was below capacity it was 9 percent above production recorded in 1976; increased output was recorded from all major mines except the North mine at Broken Hill.

Details of lead in all mine products from the States in 1977 are as follows:

		Tonnes
New South Wales		
All Broken Hill mines	231 106	
Others	3 521	234 627
Queensland		
Mt Isa	174 758	
Others	3	174 761
Tasmania		
Read-Rosebery		22 800
Other States		16
		432 204

Most of our lead concentrates are smelted in Australia. There are smelters at Mount Isa, Queensland, and Cockle Creek, NSW, which produced 156 403 tonnes of lead in lead bullion in 1977, and a smelter and refinery at Port Pirie, SA, which produced 195 055 tonnes of refined lead. Output of refined lead from other secondary producers totalled 22 950 tonnes. Domestic consumption was 76 894 tonnes (including 34 300 tonnes from scrap).

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 for lead.

The implementation of increasingly s ringent 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 1980's.

There appears to be little change in demand for most other uses of lead.

Zinc: 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 was reduced by voluntary cutbacks, industrial problems and lower ore grades. Mine production was 491 608 tonnes in 1977, from which 249 751 tonnes of zinc was refined. Although demand for zinc continued to ease, mine production increased by 6 percent mainly because of increased output from Broken Hill and Rosebery. 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 1977 production are as follows:

		Tonnes
New South Wales		
Broken Hill Mines	273 639	
Others	15 698	289 337
Tasmania		
Read-Rosebery		78 405
Queensland		
Mt Isa		123 866
Other States		-
		491 608

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

About 60% of our total zinc concentrates (all from Tasmania, and some from Broken Hill and Mount Isa) was treated at these plants in 1977. The remainder of concentrates from Broken Hill and Mount Isa was exported. In 1977, production of refined zinc was 256 441 tonnes (including 6700 tonnes from secondary sources). Domestic consumption fell to 80 533 tonnes tonnes of refined zinc, of which 73 833 tonnes was of primary origin. The decrease in consumption is attibutable in part to the overall weaker demand, but also to a substantial increase in imports of coated steel products and to the partial substitution of aluminium for zinc in 'zincalume', galvanised sheet steel coated by 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 a 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.

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

Production of tin in concentrates reached a peak of 11 997 tonnes in 1972. Production of refined tin also reached a peak in 1972, of 7027 tonnes. Production of tin-in-concentrates fell to 9507 tonnes in 1975, largely because of reduced demand, and smelter production fell correspondingly. Production has increased since then; mine production in 1977 was 10 634 of tin-in-concentrates and smelter production was 5561 tonnes of primary refined tin. With high tin prices and expansion of capacity by some mines, and installation of new plant by the smelter, mine and smelter production are likely to increase in 1978.

Imports in 1977 were 222 tonnes of refined tin; exports were 2320 tonnes of refined tin, and 13 747 tonnes of concentrates containing 5126 tonnes of tin. Estimated consumption of primary refined tin in the same year was 3760 tonnes. Consumption in 1978 will probably be about the same as this.

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

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

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

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Australia is likely to be self-sufficient in tin for many years to come. Recent high prices have counter-balanced cost increases, but it is not certain how long these prices will prevail. Published reserves in most deposits are sufficient for only a few years, although a continuation of the high prices could result in reserves being increased.

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

Copper: The first recorded production of copper was in the Kapunda field of South Australia in 1842 and at Burra in 1846. In the early years, Autralia was one of the world's leading producers, but during the first half of this century her known deposits were slowly depleted, no new ones were found, and it appeared that she would soon become largely dependent upon imports. However, this possibility was dispelled by the confirmation of very large reserves of copper ore, first discovered in 1931, adjacent to the lead-zinc lodes at Mount Isa. Since then other deposits have been found in several parts of the continent. Important discoveries of copper mineralisation have been made recently in Western Australia and South Australia. Exploration is 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 69% of the total in 1977 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 lead-zinc-copper mine in NSW is expected to begin in early 1979.

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

Domestic mine production increased steadily for many years because of expanded output from the Mount Isa and Mount Lyell mines and the commissioning of several new mines in the late 1960s and early 1970s. Record levels of production were achieved in 1973 and 1974. However, in the three years since 1974, output has been steady around 220 000 tonnes/year of copper.

In September 1977, the Mammoth mine at Gunpowder north of Mount Isa, was placed on a care and maintenance basis for economic reasons (since the record average of 76 US cents/lb reached in 1974, the price of copper has averaged 65, 69 and 66 US cents/lb in 1975, 1976 and 1977 respectively.)

Exploration diamond drilling continued on WMC's large Olympic Dam prospect at Roxby Downs in SA during 1977 and 1978 where an extensive zone of copper-uranium mineralisation from 8 to 248 m thick, with grades between 1.0 and 2.4% Cu and 0.5 and 1.0 lb U_3O_8/tonne have been intersected about 350 m below the surface.

Australia has two copper refineries - at Port Kembla and at Townsville. A third at Mt Lyell was closed down in 1969. The refinery at Townsville, a wholly owned subsidiary of Mount Isa mines, with an annual capacity recently expanded to 155 000 tonnes, is by far the larger. It was commissioned in 1959 and refined the whole of the Mount Isa output. In 1977, 84% of the copper in copper concentrates produced in Australia was domestically processed to blister or refined metal. It is expected that the level of domestic processing will rise during the next decade as mine production at Woodlawn and refinery output at Port Kembla increases and the Tennant Creek smelter is recommissioned.

Details of copper in all mine products from the States in 1977 are as follows:

		Tonnes (metal)
Queensland		
Mt Isa	152 390	
Mt Morgan	4 237	
Mammoth Mine	7 806	
Others	230	164 663
New South Wales		
Cobar	7 910	
Broken Hill lead-zinc mines (by products)	3 782	
Others	21	11 713
Tasmania		
Mt Lyell	17 690	
Others	4 312	22 002
Western Australia		
Nickel mines (by product)	4 700	4 700
South Australia		
Burra	2 403	
Mt Gunson	11 231	13 634
Northern Territory		
Tennant Creek Mines	3 898	
Others	10	3 908
Total		220 620

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OTHER METALS

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

A series of discoveries was to change this picture completely. They began in 1949 when relatively small deposits of bauxite were found at Marchinbar Island off the coast of Arnhem Land by the Bureau of Mineral Resources; this was followed by a more substantial discovery on the mainland near Gove. Later, in 1956, very large deposits of bauxite were found at Weipa on Cape York Peninsula by an exploration company; and in 1958 important new sources were recognised at Jarrahdale in the Darling Ranges close to Perth, where lateritic bauxites had been regarded as too low grade for commercial exploitation. In 1965, an announcement was made of the discovery of further large deposits inland from Admiralty Gulf in the Kimberley district of Western Australia, and in 1973 it was announced that extensive, lower grade deposits lay to the north of these, on Cape Bougainville. Exploration during the early 1970s on the land south of the Weipa deposits indicated seven hundred million tonnes of bauxite, although the grade has not been announced. Production of ore from Weipa, Jarrahdale, and Gove has mounted rapidly and in 1977 reached 26 million tonnes. Australian reserves are now known to be very large, at least 6500 million tonnes, and the largest of any country in the world apart from Guinea.

On the industrial side, developments have also been rapid, and imports of alumina have been relatively low (2197 tonnes in 1977) and used principally for purposes other than aluminium production since the commissioning of the Gladstone alumina refinery in 1967. The Bell Bay smelter, owned by Comalco Ltd, was expanded to a capacity of 112 000 tonnes/year of metal. Bauxite mining and shipping facilities at Weipa are currently capable of handling over 11 million tonnes/year. An alumina plant at Kwinana, near Fremantle, WA, with a present capacity of some 1.4 million tonnes/year, is supplying feed to the smelter of Alcoa of Australia Ltd at Geelong. Alcoa commissioned a second refinery at Pinjarra, WA, in 1972, with an initial capacity of 250 000 tonnes of alumina per year, which has been expanded in stages to its present capacity of about 2 million tonnes/year. Alcoa intends to build a third refinery at Wagerup, about 120 km south of Perth, WA. Initial capacity will be 200 000 tonnes/year although there is provision for expansion to 2 million tonnes/year. The Geelong smelter came into production in 1963 with an initial 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 157 000 tonnes/year by early 1981. Alumina is also being shipped from Kwinana to Japan, the United States and Bahrain.

The CRA - Kaiser group, in partnership with several other major overseas companies, commissioned an alumina plant at Gladstone, Qld, which processes bauxite from Weipa. The plant had an output in 1967 of some 600 000 tonnes/year of alumina; this has since been expanded in stages to 2 400 000 tonnes/year. Part of this production is used as feed for a smelter at Bluff, New Zealand, completed in 1971 by Comalco in partnership with Showa Denko KK and Sumitomo Chemical Company of Japan. The Bell Bay alumina requirement also is provided by Gladstone. The group has announced that, subject to the fulfillment of certain conditions, it had decided in principle to construct an aluminium smelter, with an initial capacity of 180 000 tonnes/year, at Gladstone, for commissioning in 1982. The bulk of the remainder of Gladstone's output is sold overseas, but part goes to Kurri Kurri, near Newcastle, where Alcan Australia Ltd established a primary smelter in 1969, with an initial production of 30 000 tonnes of metal, which reached 45 000 tonnes/year in 1971. A $45 million expansion program at Kurri Kurri has commenced, to increase production capacity to 67 900 tonnes/year by late 1979.

Early in 1969 an agreement was completed between the Australian Government and Swiss Aluminium Australia Limited and an Australian group, Gove Alumina Ltd, for a project at Gove, NT, to produce 1 million tonnes of alumina and up to 2 million tonnes of bauxite for export; initial shipments of bauxite began in June 1971 and the alumina refinery came on stream in June 1972 and reached its rated capacity of 1 million tonnes/year by mid 1973. Operating capacity is about 1.1 million tonnes/year, and this will increase by about 10 percent by 1980, following modifications to the refinery to produce 'sandy' instead of 'floury' alumina. The partners are considering the feasibility of building an aluminium smelter in Australia.

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 Newcastle.

The current position in Australia therefore is: resources of bauxite of at least 6500 million tonnes and plant capacity for the production of 6.9 million tonnes of alumina and of 248 500 tonnes of aluminium, with further expansions in train or planned. After the conditions of over-supply on the Australian and world markets in 1975, there was a marked improvement in demand in 1976, and companies progressively brought back into production capacity rendered idle during a period of cutbacks, and by the end of the year output was running at installed capacity. The three domestic smelters continued to operate at full capacity throughout 1977 and 1978.

Titanium: Australia's resources of titantium minerals (rutile and ilmenite) are considerable. Domestic recoverable reserves are put at about 10 million tonnes of rutile and 50 million tonnes of ilmenite, although almost half of east-coast reserves of rutile are currently unavailable for mining because of environmental considerations.

In 1977 Australia supplied about 96 percent of world output of rutile concentrates and about 30 percent of world production of ilmenite concentrates.

The traditional uses of rutile have been in the manufacture of welding rods and the production of titanium metal; since the early 1960s by virtue of the chloride method of processing, rutile has been used in the manufacture of pigment for high-gloss white paint, an outlet which now accounts for about 60 percent of total rutile consumption. The use of ilmenite is virtually confined to pigment manufacture. However, the commercial application of processes by which ilmenite is 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 ilmenite was rated at about 250 000 tonnes in 1977, only about 20 percent of this capacity (that in Australia and Japan) was actually utilised because of technical difficulties and reduced demand for TiO_2 feed.

The principal Australian production of rutile is from sands on and adjacent to the beaches of the eastern coast. The discovery in 1971 of old shoreline deposits of rutile, zircon, and ilmenite near Eneabba, 270 km north of Perth, constituted a major additional supply of rutile. Commercial production of rutile from this source commenced in 1975 and installed capacity for rutile production in the area is now about 150 000 tonnes/year. In 1977, production from this source accounted for about 34 percent of total domestic output of rutile concentrates. On the eastern coast much of the ilmenite which accompanies the rutile and zircon has too high a chromium content to be saleable for pigment and for the most part has been discarded or stockpiled; however, ilmenite from the more northerly deposits tends to have a more acceptable chromium content and eventually could provide a suitable base for the production of synthetic rutile in that area.

The principal ilmenite industry has been built up along the southwestern coast of Western Australia. The quality of the ilmenite from this source is most satisfactory for the manufacture of titanium white, and as ilmenite is the main heavy mineral constituent of the sands, its recovery forms the basis of the industry, together with the production of zircon, rutile and monazite. In mid 1971 Western Titanium Ltd, now a wholly-

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owned subsidiary of Associated Minerals Consolidated Ltd, commissioned a commercial beneficiation plant at Capel, WA, and an annual production rate of 40 000 tonnes of beneficiated ilmenite has been achieved. The plant is now based mainly on ilmenite from the company's operation at Eneabba and plans are in hand to expand plant capacity by about 25 percent. Both rutile and anatase pigments are produced in Australia at Burnie, Tasmania, and at Bunbury, WA. Both plants are based on the sulphate process and use ilmenite concentrates produced from the Capel deposits of Western Australia. Domestic production capacity for TiO_2 pigments is 60 000 - 70 000 tonnes/year. Ilmenite concentrates are exported from Bunbury and Geraldton, where substantial bulk loading facilities are available.

Zirconium: Australian resources of this metal, in the beach sand mineral zircon, 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-Jurien Bay 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 1977 produced 47 percent of domestic output. The market for zircon, principally required by foundries for moulds, facings and cores, and for refractories and ceramics, faced over supply in 1970 but became firm in 1973; as temporary assistance to the industry, the Commonwealth Government early in 1971 supported a stockpiling scheme initiated by industry by controlling the minimum price of zircon in export contracts. The position of oversupply quickly changed to one of short supply, and in 1973 Australia exported a record 431 000 tonnes of zircon concentrates. However, a position of potential oversupply again developed in 1975 and Government re-introduced a minimum price for zircon exports albeit almost five times as high as that in 1971. In view of the continuing adverse market situation, the floor price for zircon exports was reduced to the range \$115-\$125/tonne, f.o.b at the beginning of 1977. To allow more flexibility in approving zircon prices for export, normal export controls were reverted to in March 1977. Subsequently the market has firmed somewhat but an oversupply position, particularly for foundry grade zircon, continues.

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

Thorium and Cerium: The main commercial source of thorium, which has been of interest because of its possible nuclear uses, is the mineral monazite, a by-product of beach sand operations on both the east and west coasts of Australia. Notwithstanding the use of thorium in several United States experimental reactors, large-scale nuclear uses in fast breeder reactors are said to be many years off. Although research on the nuclear application of thorium continues, commercial application of the thorium-uranium fuel cycle in the high-temperature, gas-cooled reactor (HTGR) as an industrial source of high temperature heat 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 1977 (compared with ten years ago) are: catalysts 43% (63.0%), metallurgy 35% (6.4%), glass and ceramics 14% (30.0%), TV electronics, nuclear and miscellaneous 8% (0.6%). Cerium is also present in the mineral allanite, large quantities of which are found in the Mary Kathleen uranium deposit.

High-grade monazite concentrates are recovered from beach sands in Western Australia, Queensland, and New South Wales. The monazite recovered in the southeast corner of Western Australia is a by-product of ilmenite production, but elsewhere of rutile and zircon production. Development of extensive mineral sands deposits commenced at Eneabba about 270 km north of Perth in 1973, and the area is now a major world source of monazite. In 1977 Australian production was 9379 tonnes of concentrates containing about 8507 tonnes of monazite, 84% of which came from Western Australia;

Australian production was about 55 percent of total world output of monazite in 1977. All sales were overseas before 1969, but a former uranium plant, purchased from the South Australian Government at Port Pirie, was commissioned in May 1969 to process domestic monazite. In early 1972 an annual throughput of 1300 tonnes of monazite concentrate was achieved at the plant for the production of cerium and lanthanum hydrates, yttrium oxide, thorium sulphate, and tri-sodium phosphate. However, financial and market difficulties forced closure of the plant in mid 1972.

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

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

Domestic production of antimony in antimony concentrates in 1977 was 1526 tonnes, nearly all of which was exported. In addition 563 tonnes of antimony from Broken Hill concentrates was recovered in antimony alloys produced at Port Pirie. An additional 66 tonnes of antimony was contained in retreated tailings from the old Costerfield mine dumps. In 1977, the Port Pirie lead refinery produced 10 150 tonnes of antimonial lead and 9604 tonnes of lead sheathing alloy containing 868 tonnes of antimony of which 401 tonnes was recovered from scrap.

Exports of antimonial lead alloy in 1977, mainly to Malaysia, New Zealand, and Taiwan, amounted to 7330 tonnes valued at $4 026 000. In early 1977 Quelar Chemicals established a small electrolytic antimony refinery in Brisbane, Qld. 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.

Fifty-eight tonnes of antimony metal, valued at $141 000, were imported; Mainland China was the main supplier.

Antimony ores have been produced in Australia since the middle of the last century, but most deposits have been worked out. Recently, the only significant production has come from mines in the Hillgrove area in northeastern NSW - in 1977 production was 1002 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% antimony 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; output in 1977 totalled 508 tonnes of antimony in concentrates. Recovery of antimony was lower than expected and the weak antimony market resulted in a build up of stocks and a substantial operating loss which culminated 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.

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

Australian production of beryl began in 1939 and reached a peak in the war years. It fell away soon afterwards and production in 1967 was only 55 tonnes containing some 6.9 tonnes of beryllium oxide. However, the same year saw exports totalling 637 tonnes of beryl, nearly half to Japan, obtained largely from stockpiled material in Western Australia; there has been no subsequent record of exports to Japan. Production was 20 tonnes of contained BeO in 1973 before falling to 9 tonnes in 1974. There was no recorded production in 1975, 1976 or 1977, although exports of beryl concentrates were resumed from Western Australia in 1977 and totalled 14 tonnes valued at $2839, all to USA.

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

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

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

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

Tantalum-Columbium: Tantalum and columbium (niobium) are metals used in alloying, in high-temperature corrosion-resistant chemical ware, for tipped tool cutting purposes, and in anodes and grids for electronic equipment. Australia is an important producer of the ore (tantalite-columbite). This is from Western Australia, mainly as a by-product of tin mining. Production amounted to about 158 tonnes of combined concentrates in 1977; and was all exported. There is no domestic demand but if one arose in time of emergency, available supplies could most probably satisfy the requirement.

Selenium and Tellurium: Selenium is used in small quantities in the elctronic, 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 elctrolytic 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 1977 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: 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 domestic 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 of 1 169 700 kg was recorded in 1974 but production declined subsequently and in 1977 totalled 912 000 kg. The bismuth occurs with copper and gold and much of the bismuth reports in copper-bismuth flue dust, a by-product of copper smelting. Research is continuing into methods of processing bismuth concentrates to bismuth bullion containing about 90 percent bismuth metal. Imports of bismuth metal totalled 13 999 kg in 1977, having ranged between 5000 and 22 000 kilograms 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 and Calcium: These are derived from the similar sources dolomite and limestone, of which Australia has an abundance. Elsewhere in the world, magnesium is produced from seawater; however, there is no production of magnesium in Australia. Magnesium is well known as a light-weight metal, being only 2/3 of the weight of aluminium. Suitably alloyed to increase its strength, it has been used increasingly in the aircraft and allied industries. Calcium is a soft metal, of little use on its own, but effective as a hardener of lead. Neither metal is produced in Australia, although magnesium was smelted in limited amounts at Newcastle during the war. Australian resources for production are more than ample.

Mercury: Australian reserves of mercury are negligible. Mercury was produced early in 1967 for the first time since 1945. In 1977 21 kg of mercury metal was produced as a by-product during refining of Rosebery lead-zinc ores at Risdon. The mercury is recovered as an HgS slime containing about 2% mercury. This is a preventative measure against possible pollution of the Derwent River by refinery effluent. Imports of mercury in 1977 were 43 899 kg; China was the major supplier, accounting for 77 percent of total imports, followed by Spain (14 percent) and Japan (8 percent). World production during 1977 was some 8.2 million kg. World consumption of mercury continued to decline in 1977 because of pollution fears and demand for mercury is expected to increase at an annual rate of less than 1 percent through 1980.

Silver: Most of the silver mined in Australia is mined as a by-product of lead mining, but some is also produced as a by-product of zinc, copper, and gold mining. Mine production in 1977 was 856 110 kg most of which came from the lead-zinc industry. Silver refined in Australia in 1977 was 280 129 kg and almost all the rest of the silver mine production was exported in base-metal concentrates, or lead bullion.

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

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

In 1977, mine production of cobalt totalled 3324 tonnes, of which 122 tonnes were contained in zinc concentrates from Broken Hill, NSW, 1125 tonnes in nickel concentrates produced in Western Australia and 2077 tonnes in lateritic nickel ore mined at Greenvale in Queensland; however, only a small proportion is recovered in Australia. The zinc refinery at Risdon, Tasmania, which continues to be the major supplier of cobalt for Australian industry, produced 25 tonnes of cobalt oxide (18 tonnes of cobalt) from zinc concentrates in 1977. Nickel-cobalt sulphide products are produced at the nickel refinery at

Kwinana and the Yabulu refinery near Townsville. In 1977 the cobalt content of materials from both these sourves was 813 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 requirements are imported in the form of metal and compounds, mainly from Zaire (the world's principal producer), Canada, Morocco, and Zambia. The USA is an alternative source from which imports are also obtained. Following military activity in Zaire, the producer price of cobalt has increased from US$5.20 to US$20.00/lb and freemarket prices have reached US$41.00/lb.

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

Production of refined cadmium in 1977 was 670 tonnes of metal; 428 tonnes came from Risdon, 226 tonnes from Cockle Creek, and 16 tonnes from Port Pirie. Mount Isa produces a cadmium-thallium sponge which is exported, and reported production of 8.4 tonnes of this material in 1977. Estimated domestic sales in 1977 were about 118 tonnes and the rest was exported, including cadmium contained in lead-zinc concentrates. Australia is more than self-sufficient in this metal, but the United States, Canada, and Japan are alternative sources.

<u>Gold</u>: Annual production of gold, once steady at above 1 million ounces (32 150 kg) has been falling slowly for a number of years. In 1970, reflecting the difficulties confronting the gold mining industry, mainly resulting from fixed prices, production fell to 17 600 kg. However, rising gold prices in 1971 and 1972 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 1977, with the contribution from a major new mine, Telfer, WA, and with the encouragement of rising prices, production rose to 19 417 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 three-quarters of Australian production. Of this three-quarters, 70 percent came from Western Australia in 1977. In terms of total 1977 production, however, 55 percent came from Western Australia, 10 percent from Tasmania, 6 percent from Queensland, with small contributions from NSW and Victoria. The remaining 27 percent came from the Northern Territory where, because of low copper prices, Peko-Wallsend Ltd concentrated on the gold-rich portions of the orebodies in the area and stopped production of copper. Peko-Wallsend's Juno gold mine, however, stopped producing early in 1977.

Although Australia imports around 2000 kg of gold annually, mostly as unrefined bullion, its annual exports total about 10 000 kg of refined gold, and so despite decreased production in recent years, it remains a net exporter of gold.

The major disability suffered by the gold mining industry in recent years was that whereas the price of gold had been fixed for more than 30 years, the cost of production had mounted steadily. In order to keep marginal mines in operation and to maintain existing communities in a number of isolated places, the Commonwealth Government introduced various forms of assistance, including a subsidy on production which was last increased in January 1972. However, subsidy payments cut out when the price exceeded $54 per oz. Gold's main use was that of a Foreign exchange earner, with a world price of US$42 per troy oz. However, in 1968 the International Monetary Fund agreed to a two-tier system under which gold might be traded at higher than the official price; in general, this system together with other measures induced a rising free market price for gold, and promised some rejuvenation of gold mining in Australia, but this promise was not fulfilled. The two-tier system was abandoned in November 1973. Production is expected to decrease slowly in the future. The price of gold was US$195/fine ounce at the end of 1974 but by the end of August 1976 it had fallen to US$103/fine ounce. From this low point it recovered slowly and in December 1977 the price was about US$170/fine ounce. With the continuing weakness of the US $.

the price rose steadily in 1978, averaging over US$190 for the year, reaching a maximum of US$242.60 on October 31, and falling slightly to US$200 in December 1978.

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

The Gold Mining Industry Assistance Act, under which the subsidy was payable, lapsed on 30 June 1975. The position remains that Federal Assistance to the gold mining industry consists of concessions provided under Section 23(a), 23C(1), and 23C(2) of the Income Tax Assessment Act 1936 as amended. The main provision is Section 23(a), which states that all income derived from a mining operation directed principally to obtaining gold, or gold and copper, is exempt from tax, except that where both gold and copper are produced the value of the gold must not be less than 40 percent of the total value of the output of the property, excluding the value of pyrite.

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

Platinum is now recovered from nickel co-products produced at the Kwinana nickel refinery. In 1977 production from this source was 121 kg of platinum group metals.

Imports in 1977 were valued at $3.28 million and exports of 2236 were valued at $1.5 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 the USSR are not as consistent as South Africa, because the quantity of platinum-group metals produced in the first two countries is dependent on the quantity of nickel produced, and will decrease when 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 1977, e.g. Australia imported 26 413 kg, mostly from the Federal Republic of West Germany (re-exports from that country) and re-exported 2236 kg, mainly to Malaysia and Hong Kong.

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, used in many industrial cutting processes, and in corundum and emery. Production of all these is negligible. Small amounts of industrial diamonds were once obtained as a by-product of gold dredging in the Macquarie River, New South Wales, but today the total domestic requirement is imported; imports totalled 1 015 206 metric carats in 1976-77, but a considerable amount (243 886 carats) was re-exported. The Republic of Zaire is the world's major producer, followed by the USSR and other African countries. Currently there is a boom in diamond exploration in the Kimberley district of Western Australia following encouraging reports by one large consortium of diamond occurrences in kimberlite pipe structures, and by late 1978 over 1200 exploration licenses had been taken up.

Corundum and emery have been mined on a small scale in Western Australia but there is now no domestic production, and imports commonly amount to about 1300 tonnes, mainly for use in optical polishing. Rhodesia is the world's leading producer of corundum followed by the USSR and South Africa. Turkey is easily the largest producer of emery.

Part of our requirement of garnet is normally obtained as a by-product of mining mineral sands along the eastern coast; a production of 1104 tonnes was recorded from this source in 1977. The bulk of domestic requirements is met by imports, mainly from the United States. Trial shipments of garnet bearing sands from near Port Gregory, WA, were forwarded to potential buyers following exploration and testing during 1977.

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

Arsenic: In 1975, Copper Refineries Pty Ltd at Townsville commenced production of copper arsenite at the rate of about 200 tonnes/year. This is the first recorded production of arsenic on a commercial scale since 1952. Another company is purchasing arsenical solutions from the Broken Hill Associated Smelters Pty Ltd and is using them also as the basis for the manufacture of wood preservative. Apart from these two sources all domestic requirements of arsenic are imported. A total of 685 tonnes of arsenic trioxide was imported in 1977.

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

Asbestos: Australia has large resources of blue asbestos (crocidolite) in the Hamersley Range, WA. Deposits of crocidolite near Wittenoom were worked, mainly for export, until 1966 when production ceased because of rising costs. There are few known deposits of amosite or of white asbestos (chrysotile) in Australia. However, the chrysotile deposit at Woodsreef near Barraba, NSW, which contains demonstrated reserves of 38 million tonnes of fibre-bearing rock, was brought into production in January 1972; output in 1977 was 50 601 tonnes of fibre (exports were 20 510 tonnes). A small quanity of chrysotile asbestos is also produced at Baryulgil, NSW. The domestic product is dominantly short to medium fibre and although this satisfies local demand and provides exports to Japan, imports of longer fibre chrysotile and of amosite remain significant. Imports in 1977 were 43 779 tonnes of chrysotile, 11 129 tonnes of amosite, and 19 359 tonnes of other varieties, mainly chrysotile fines. Canada supplied 84 percent and South Africa 15 percent of Australian asbestos fibre imports.

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

<u>Barite</u>: 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 1977 was 11 675 tonnes; most of this was from South Australia, mainly from the Oraparinna region in the Flinders Ranges, but also from Olary. 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. 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.

Consumption of barite in Australia in 1977 was estimated by BMR as 9000 tonnes, of which about 4500 tonnes was reported to have been used in petroleum drilling. Australian barite is generally only of drilling grade but is also used in X-ray shielding plasters and concretes. High-quality industrial-grade barite, used as a filler and extender in paper, paint, varnish, glass, rubber and plastics, is imported. In recent years imports have come mainly from China.

Australia also imports various barium chemicals; the main ones (and 1977 imports) are: precipitated barium carbonate (676 tonnes), precipated barium sulphate (blanc fixe, 177 tonnes), lithopone (barium sulphate and zinc sulphate, 115 tonnes) and barium chloride (115 tonnes). The barite equivalent of these chemicals, not included in BMR's consumption estimate of barite, is about 1700 tonnes.

Australia has adequate resources of barite which could be brought to production to meet its strategic requirements. However, most are in remote localities mainly in Western Australia and South Australia, and as economic development of deposits of minerals of low unit value is restricted by transport costs, domestic requirements will continue to be partly met by imports.

<u>Bentonite and Fuller's Earth</u>: The Australian demand for bentonite has decreased in recent years, reflecting mainly the decline in petroleum drilling. Important uses continue to be as a bonding agent in iron ore pellets and in moulding sands. Local production of bentonite in 1977 was from Queensland (224 tonnes), New South Wales (5232 tonnes), and Western Australia (147 tonnes), and imports totalled 13 191 tonnes; 50 tonnes of fullers earth was produced in 1977, compared with 9 tonnes in 1976. Deposits of bentonite in various States are being tested, and it is possible that Australian production may rise substantially in the future, although domestic freight rates present restraints to exploitation of new deposits. The United States and Italy are the main world producers of high quality bentonites, which are in heavy demand for drilling muds.

<u>Diatomite</u>: There are many small deposits of diatomite in Australia and small-scale production has been almost continuous since 1896; production in 1977 was 1288 tonnes and came from the Toowoomba Mining District, Qld, from Coonabarabran, NSW, Mount Egerton, Vic., and Eneabba, WA.

Apparent consumption of diatomite in Australia in 1977 was 10 900 tonnes most of which was imported, mainly from USA. 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.

<u>Felspar</u>: Uses are mainly in the glass and ceramics industries and as an abrasive. Australian resources are large and more than enough for any likely requirement. Present centres of production are Mukinbudin and Rothsay, WA, and Broken Hill, NSW, for the potash varieties and the Olary District, SA, for the potash-soda varieties. Production in 1977 was 1877

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.

In 1977 Australian consumption of all grades of fluorspar was 30 000 tonnes. The steel industry is the largest consumer of fluorspar and BHP Co. Ltd used about 14 000 tonnes of metallurgical-grade material in 1977, as a metallurgical flux for the removal of impurities in the manufacture of steel. The balance of 16 000 tonnes represents mostly acid-grade material used mainly in production of anhydrous hydrofluoric acid (HF); there are two HF plants in Australia, at Newcastle, NSW, and Camellia, NSW. Hydrofluoric acid is an intermediate 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 by nearly 20 percent in 1977, compared to the previous year, because alternative propellants are being used while the controversy on the effect of fluorcarbons on the earth's ozone layer continues. 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/or 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, both used in aluminium smelting, are the most important. In 1976-77 the total f.o.b. value of imports of fluorochemicals was $5.96 million. Because fluorspar is a major source of fluorine, resources are measured in tonnes of contained fluorine. Of total Australian identified resources of fluorine of 65.23 million tonnes, only 3.29 million tonnes occurs in fluorite deposits; by far the greatest portion of indentified resources is contained in the fluorapatite which make up 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: This mineral has extensive uses as a lubricant, and is employed in many manufacturing processes, for moulding, for graphite crucibles, and in lead pencils. Local production was last recorded in 1963 and so far no high-grade deposits have been discovered in Australia, although possible resources have not been fully investigated. All our requirements are met by imports, which amounted to 1720 tonnes in 1977 (mainly from China, Korea, Sri Lanka and France), plus 1186 tonnes of artifical 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 1977 limestone production was 10.55 million tonnes. Dolomite production for use as flux in the steel industry and in refractories was 536 790 tonnes.

Mica: Although Australia's resources are probably large, production, because of cheap overseas supplies, has been minor and in 1978 no mica was produced in Australia. While the Commonwealth Mica Pool operated, during and after World War II, a series of small mines in the Harts Range in the Northern

Territory produced most of our requirement. With the winding up of the Mica Pool in 1960, most mines ceased production.

Imports in 1977 amounted to 1088 tonnes mainly from India, China and South Africa. In the event of an emergency, Australia's domestic industry could probably be revived to meet her requirements. Alternative sources of supply include Argentina, Brazil and Malagasy Republic.

Quartz Crystal and Silica: Australia is self-sufficient in various forms of silica used in glass making, foundry sands, refractory bricks, etc., but there has always been an acute Australian shortage of high quality quartz crystal, which has piezo-electric properties that are extremely useful for 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 - namely, 70 tonnes in 1974. Imports of quartzite and natural quartz amounted to 441 tonnes in 1976-77. Recent developments overseas in synthesising quartz crystals have eased pressure on the need to discover indigenous sources. Some 494 797 tonnes of high-grade silica sand were exported in 1976-1977 mainly to Japan from deposits near Cape Flattery, north Queensland, and also from deposits near Perth, WA.

Sillimanite and Kyanite: These minerals are consumed chiefly in the manufacture of high-alumina refractory linings used in furnaces. Deposits of sillimanite are known in several parts of Australia, mostly in remote localities, and currently the only production is from Mount Crawford, SA. Mineral sands in the Eneabba-Jurien Bay area of Western Australia are a large potential source of kyanite, although to date there has been 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

550 tonnes in 1977 and imports were negligible. Imports of kyanite have been greater, and in 1977, imports under an item which included kyanite, sillimanite, andalusite, mullite and dinas earth, totalled 1451 tonnes, mainly from South Africa (974 tonnes) and the United States (467 tonnes).

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

Talc, Steatite, and Pyrophyllite: The chief consuming industries are cosmetics, rubber, ceramics, and paint. Deposits are known in most of the States and, in recent years, Three Springs and Mount Seabrook in Western Australia, and Mount Fitton and Gumeracha in South Australia have been the chief producers. Production of talc in 1977 was a record 112 920 tonnes, of which 87 271 tonnes was exported. Imports, mainly of varieties not available domestically, were 335 tonnes. Production of pyrophyllite from New South Wales totalled 16 039 tonnes, the bulk of which was from Pambula on the south coast. The United States is the leading producer of talc and Japan is the major producer of pyrophyllite, Australian imports have come from Mainland China, United States, and India as well as Italy and Norway.

Vermiculite: This mineral has the unusual property of expanding to many times its original volume when 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. Production in 1976 was 716 tonnes; there was no production in 1977. A small amount is imported annually (2816 tonnes in 1977), South Africa being the main supplier (68 percent), and China (31 percent). The United States and South Africa supply almost the entire world production.

Salt & Sodium Compounds: Salt production in Australia is all by solar evaporation, mainly of sea water but also of lake and delta brines. Most of Australia's production is from four large producers in Western Australia and this is nearly all exported, most of it to Japan. Australia's own salt requirements are provided by various smaller operations based 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 million tonnes/year of new salt capacity was constructed and commissioned in that period. However export demand has slackened since 1974 and the export arm of the industry is presently suffering from an excess of productive capacity. In support of the industry, the Australian government set a minimum f.o.b. price of US$8.13/tonne for salt exports from March 1976; pre-existing contracts with appropriate provisions were exempted from control. The government lifted the control in March 1977 on the basis of undertakings given it by exporters, that exports would continue to be made at current prices and that new export proposals would reflect world prices.

Australian salt production in 1977 was 4.72 million tonnes; production from Western Australia, nearly of of it exported, accounted for about 80 percent of this. The large export-oriented operations in Western Australia are located at Dampier (Dampier Salt Limited), Lake McLeod (Texada Mines Pty Limited), Port Hedland (Leslie Salt Co.), Shark Bay (Shark Bay Salt Pty Ltd) and Lake Lefroy (Lefroy 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 who produce 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 near 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 (Whyally, 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 salt consumption is more evident in household preparations and in food processing, 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 a net exporter 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 also consume chlorine. Chlorine is used in a variety of chemicals and in many applications; its more important uses are as a bleaching agent, particularly in the paper industry, and in the petrochemical industry for manufacturing vinyl chloride which is a basic building block of many plastics.

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

<u>Gypsum</u>: The mineral gypsum is hydrated calcium sulphate which, for its formation, 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 1977 Australia produced about 900 000 tonnes of gypsum, about 75 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, Millewa, Nowingi, and Bronzewing in Victoria, and a smaller amount is produced from the Cobar Mining Division in New South Wales.

Australian exports of gypsum in 1977 totalled nearly 200 000 tonnes and were valued at $1.69 million; imports are negligible.

Calcined gypsum or plaster of paris is widely used in the building industry as 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 used as a fertiliser and soil conditioner.

Australia's gypsum resources are very large; demonstrated reserves total more than 760 million tonnes.

<u>Pigments and Ochres</u>: The term is here used to mean natural earth pigments such as the iron oxides, stained clays, and slate powder which are used to give colour or body to paints, plaster, cements linoleum, and rubber. A number of small deposits have been worked over the years and Australia undoubtedly has large resources of the iron oxide variety. In recent years, red and yellow ochres have been mined in the Ulverstone-Penguin area of northwest Tasmania and red ochre has been produced in the Weld Range area of Western Australia. Production of mineral pigments in 1977 totalled 62 tonnes (red ochre and micaceous hematite). Domestic consumption is small. Some 12 000 tonnes of natural and synthetic iron oxides were imported in 1976-77.

Sulphur-bearing materials: Commercial deposits of elemental sulphur and sulphur-bearing ("sour") natural gas are not known in Australia and in recent years 50-70 percent of domestic demand for sulphur has been met by imports, mainly from Canada and the United States. Imports in 1977 of 408 000 tonnes were valued at $12.87 million f.o.b. Several oil companies recover sulphur from the processing of imported crude oil; 10 590 tonnes of sulphur was recovered from oil refining operations in 1977. Although combined capacity of 6 recovery plants is about 52 000 tonnes/year of elemental sulphur, actual production depends on the sulphur content of the refinery feedstock and this has been declining since low-sulphur Bass Strait oil replaced high-sulphur imported crude. 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 1977, 38 percent of all Australian sulphuric acid consumption of 1.80 million tonnes was of acid recovered from indigenous material as a by-product 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, NSW and Cobar, NSW), Port Pirie, SA, (lead concentrate from Broken Hill) and Risdon, Tas. (zinc concentrates from Broken Hill and Rosebery, Tas.). A pyrite-based acid plant, which uses by-products pyrite concentrates from Mount Lyell, Tas. and Rosebery, is located at Burnie, Tas. Western Mining Corporation Limited 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 minerals dates back mainly to the early 1950's when brimstone was in short supply and the Federal Government introduced incentives, by way of bounty payments, to promote self-sufficiency. Later, when changing circumstances abroad increased the supply situation, the Government announced that bounty payments would not be renewed after June 1965 but, on re-consideration, the Sulphuric Acid Bounty Act was first extended to 1969, and then to 1972, when it lapsed.

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Imported sulphur is used mainly for manufacturing sulphuric acid which, tobether with most of the acid recovered from indigenous materials, is used mainly for manufacturing phosphatic fertilisers, particularly single superphosphate. Of total acid consumption in 1977 in Australia (1.80 million tonnes), nearly 70 percent was in phosphatic fertilisers; 18 percent was in general chemicals and 12 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 its use in lead-acid accumulators. 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 30 000 tonnes/year of elemental sulphur are consumed in Australia for other-than-acid uses of which the main ones are 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. These trace elements 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 1977, in terms of single-superphosphate equivalent, was 3.29 million tonnes. Consumption of superphosphate in Australia has traditionally been subsidised by the Federal Government; presently the superphosphate bounty is $139/tonne available P, equivalent to $12/tonne for single-superphosphate, the most commonly used phosphatic fertiliser.

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 form because, with existing plant, it is more difficult and costly to process this rock than the rock to which they are accustomed and for which existing plant has been designed. Specifically, the unbeneficiated rock produced by BH South (which is called "direct shipping-grade rock") is harder and more difficult to grind with existing plant, and it liberates more fluorine during processing, than rock from traditional sources. Both problems could be solved, either by BH South beneficiating its product or by manufacturers modifying their plant; both options require capital investment which both parties are reluctant to spend at this time. BH South sought financial assistance from the Federal Government but this was not granted and the company closed the operation on 30 June 1978 for economic reasons; the project is on care-and-maintenance.

A small quantity of phosphate rock is also produced in South Australia but the material is not suitable for superphosphate manufacture because of its high aluminium and iron content, and, after crushing, is applied directly to the soil by local users; production in 1977 was 11 186 tonnes.

Australia's requirements for phosphate rock have traditionally been imported from Nauru and Ocean Island in the Pacific Ocean and Christmas Island in the Indian Ocean. Production from Ocean Island will stop after 1979-80 when the Island's reserves will be 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. 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 1977 totalled 1.44 million tonnes and were valued at $48.04 million, f.o.b.

Australia's identified resources of phosphate rock are substantial; reserves are assessed as 2770 million tonnes rock of average grade 7.39% P, and identified subeconomic resources are assessed as an additional 2529 million tonnes rock of average grade 5.59% P. Reserves on Christmas Island are sufficient for only about 10 years at present rates of extraction.

Potash: Potassium, together with nitrogen, phosphorus and sulphur, is one of the four main nutrients essential for plant life. Potassium deficiences 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 1977 Australia imported about 158 000 tonnes of potassium chloride and about 17 000 tonnes of potassium sulphate; the total value of imports was $10.19 million, f.o.b.

Potassium also occurs as a constituent of the mineral alunite, 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 million tonnes of alunitic red mud in Lake Campion, WA, about 50 km north of Merredin. The deposit was worked to 1949, when operations ceased for economic reasons; the venture produced about 13 000 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 were produced in the previous 60 years.

In November 1973 Texada Mines Pty Ltd commissioned plant to produce langbeinite ($K_2 Mg_2 (SO_4)_3$) from the residual brine liquor of its salt (sodium chloride) producing operation at Lake McLeod, WA. The project was beset by technical problems, declining export markets and ultimately by flooding. The langbeinite operation has since been put on care-and-maintenance pending further feasibility studies. About 10 000 tonnes of material, produced and stockpiled during progressive commissioning of the plant, was sold overseas in 1976 after BHP bought a controlling interest in the company.

Nitrates: 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 in New South Wales 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 in 1976-77 as tonnes; BMR also estimates the nitrogen content of imports of various nitrogenous fertilisers in 1977 as 11 000 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 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 contained N from 1 January 1977; a further reduction in 1978 has also been deferred.

ENERGY MINERALS

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 1977 Australia was the ninth-largest black coal producing nation, accounting for about 3 percent of world production; raw coal production increased to 87.4 million tonnes for a saleable coal output of 70.9 million tonnes.

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; 87 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 Blair Athol, Callide, Ipswich and Maryborough for use by electric power stations and/or local industry.

Coal mined in New South Wales is bituminous and nearly all is mined in the Sydney Basin. In 1977 underground mines accounted for 78 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 on the South Coast and in the Burragorang Valley. About one third of this coal is used at the Port Kembla steelworks and the remainder is exported.

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

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 (South Australia) and from underground and open-cut mines at Collie (Western Australia). Minor quantities of non-coking coal are mined for use by local industry at Fingal in Tasmania.

In 1977 domestic consumption increased to 32.1 million tonnes mainly because of an increase in consumption for electricity generation which more than offset decreased consumption by the iron and steel industry. Consumption in electricity generation accounted for 63 percent of total consumption and consumption in the iron and steel industry accounted for 25 percent of total consumption.

Australia is a major exporter of black coal. In 1977 it was the third-largest exporter of black coal; the 36 million tonnes exported accounted for about 18 percent of world trade and was valued at about $1400 million, making coal Australia's largest single export earner.

Exports to Japan increased slightly, despite a continuance of reduced demand in the world steel industry, accounting for 73 percent of total exports and consisted of 26 million tonnes of coking coal and about 0.4 million tonnes of steaming coal. The remaining coal comprising about 7.1 million tonnes of coking coal and approximately 2.5 million tonnes of steaming coal was exported mainly to Europe and Southeast Asia.

The need in the coming years to conserve certain energy forms, especially oil and gas, because of depletion problems, will result in a swing away from these energy forms to coal, nuclear, and possibly solar power. There are only a limited number of countries which 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. 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 demonstration 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. Bowever, except for the brown coal deposits in Gippsland, Bacchus Marsh, Altona and Anglesea in Victoria and two deposits in the St Vincent's Basin, South Australia, other known deposits are either twoo 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 and the industry has reached a high degree of sophistication in mining, on-site development for power generation, briquetting and char manufacture.

Production of raw brown coal in 1977 totalled 29.3 million tonnes; more than 95 percent was produced by the State Electricity Commission at Yallourn and Morwell and the remainder was produced 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, therefore, 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 and 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.

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 spectacular period as a producer of uranium ore and we are now on the thresh-hold of becoming a more important producer. The national search for deposits began in 1944 and bore its first fruit in the discovery of Rum Jungle in 1949 and of Mary Kathleen in 1954. Some small deposits were known in South Australia as early as 1906, and others, which were to become useful but minor contributors to the output, were found in the South Alligator area, NT, in the early 1950's. Treatment plants for the production of uranium oxide were erected at Port Pirie, where for several years rather high-cost material was produced from ores mined at Radium Hill; Rum Jungle, where the plant remained in operation treating stockpiled ores until 1971; Moline, NT, which after fulfilling the last part of an overseas contract for uranium was modified to treat Ag-Pb-Zn ores from Mount Evelyn pending resumption of uranium mining; and Mary Kathleen which commenced operation 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 Governmnet agreement. In the event the prices secured by Australia in several of her long-term contracts turned out to be extremely good, and long before the contracts were fulfilled alternative sources overseas were able to supply more cheaply. At the same time dwindling defence needs and the lack of any comparable requirement for peaceful purposes led to a situation in which no market existed for the Australian product once contracts were fulfilled.

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

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

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 Queensland; near Lake Frome and at other localities in South Australia; at Yeelirrie in Western Australia; and, of prime importance, the substantial deposits at Ranger 1, Nabarlek, Koongarra, and Jabiluka about 230 km east of Darwin, in a major new uranium province in the Northern Territory. Reserves of uranium ore extractable at costs up to $US80/kgU were assessed at June 1978 by the AAEC to be 290 000 tonnes U, which is about 18% of the world known resources extractable at that cost.

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 1977 output was 356 tonnes U in yellowcake.

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

There was a dramatic increase in world demand for uranium in 1975 and 1976, with prices for spot sales increasing from $US10.50/lb U_3O_8 in 1974 to about $40/lb U_3O_8 at the end of 1976. The increased prices reflected the concern that there could be a shortage in the mid 1980s. Prices have remained at $US42.50 - 44.00/lb U_3O_8 since December 1977.

Australia is well endowed with uranium resources which account for about 12% 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.

Petroleum:* Australia's main mineral deficiency has long been that of indigenous petroleum particularly crude oil, the lack of which has compelled her to import significant amounts of crude oils and refined products to meet her increasing consumption. In 1977 the value of imports of refinery feedstock and refined products rose to $1103.8 million (crude $716.04 million) from $861.7 million (crude $562.6 million) in 1976, mainly as a result of increased imports; imports accounted for about 39% of Australian petroleum requirements; indigenous crude oil supplied about 68.7% of demand in 1977. The increase in consumption of marketable petroleum producs in 1977 was 4.1% over the previous year, but demand is expected to almost double in the next 10 years. The average annual increase in consumption of the same range of products for the five years ended 31 December 1977 was 3.8 percent.

With the first full year of production from Moonie in 1965 the first step was achieved in the national effort to become self-sufficient. In 1967 output from Moonie, Alton, and Barrow Island was 1.2 million cubic metres (7.6 million barrels), an increase of 124% brought about mainly by Barrow Island coming into production. This represented 5.1% of consumption as compared to 2.7% in 1966. In 1968, Australian indigenous production was 2.16 million cubic metres (13.8 million barrels), in 1969, 2.51 million cubic metres (15.8 million barrels), or 8.8% of total petroleum consumption, and 10.35 million cubic metres (65.1 million barrels) in 1970. Production rose rapidly to 17.95 million cubic metres (112.9 million barrels) in 1971 as the Gippsland Shelf fields came on stream. In 1977 indigenous crude oil production was 24.98 million cubic metres (157.7 million barrels).

Since the mid 1950s an Australia-wide search has been going on, with mounting intensity in the 1960s. In 1966 some 101 exploratory wells were drilled in Australia (excluding PNG) (compared with 14 in 1959); in the succeeding years, the number ranged from 72 to 119, then fell from 100 in 1972 to only 20 in 1976 and 21 in 1977 but rose significantly to 53 in 1978. Based on exploratory programs announced for 1979 the number of exploratory wells could rise slightly, to between 56 and 66 in this year.

* Prepared by Petroleum Exploration Branch

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 Australian Government did not renew this subsidy scheme after June 1974, but established a Petroleum and Minerals Authority with powers and responsibilities in fields of petroleum and minerals exploration and development. However, the High Court in July 1975 ruled that the Act establishing the Petroleum and Minerals Authority was invalid.

Incentive was further increased by the commercially viable oil and gas discoveries encountered during the years since 1960. These include the gas fields in the Roma area in Queensland and the Kincora and Silver Springs gas fields now supplying Brisbane with natural gas; the Gidgealpa - Moomba - Big Lake (and the nearby Toolachee) gas fields in South Australia, now supplying Adelaide and Sydney with natural gas; the Gippsland Shelf major gas/oilfields Barracouta and Marlin supplying Melbourne, and the Dongara field in WA now supplying Perth. Other gas fields still to be developed are, Mereenie - Palm Valley in the Northern Territory and fields on the North West Shelf off Western Australia. Gas has also been discovered in the Tern well, 300 km west-southwest of Darwin, and several major discoveries of natural gas on the Northwest Shelf are being appraised and production plans formulated.

Crude oil was discovered at Moonie and Alton in Queensland in 1961, and these fields have been producing since 1964. Following this, the Barrow Island oilfield in Western Australia began commercial production in December 1966. The most prolific crude oil discoveries were the Kingfish and Halibut fields in the Gippsland Basin in Bass Strait; significant discoveries were made in the Barracouta, Marlin, Mackerel, Tuna, Flounder, Cobia and Fortesque fields in the same basin.

Commercial production began from Barracouta in late 1969 and was followed by Halibut in 1970, Kingfish in 1971 and Mackerel in 1977. Tuna oil field is to be brought into production in 1979. At the end of 1978 development drilling was in progress on the Mackerel and Tuna platforms.

At the end of 1977, some 272 wells were on production in the Barrow Island field, and total daily crude oil production was around 5083 cubic metres per day (35 [illegible] barrels per day). The scccess of the water flood technique introduced in this field in early 1968 has stimulated production, and it is hoped that this daily rate will be sustained for some time.

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

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

Production of crude oil and gas from this prolific area began in 1969, and by the end of 1977 crude oil production was some 63 190 cubic metres per day. Natural gas production from this area also began in 1969 and some 3256 million cubic metres were produced in 1977.

Further offshore drilling units arrived in Australia, and by mid-1969 six mobile units were operating in Australian coastal waters. Three of these units were drill ships, two were semisubmersible platforms, and one was a jack-up unit. However, only two units, Ocean Digger and Ocean Endeavour, both Australian flag units, were in operation at the end of 1976. At the end of 1978 four mobile offshore units were active and two platform rigs were active on the Mackerel and Tuna platforms.

The year 1969 saw the completion of three major natural gas pipelines. The 170 km, 30 inch pipeline from Longford to Dandenong commenced delivery to Melbourne and its environs in early 1969, and in the September quarter of 1978 was delivering about 12.6 million cubic metres per day (446 million cu.ft/day).

Brisbane received its first delivery of natural gas from the Roma area in March 1969 through the 10¾ inch, 410 km pipeline. Production from this area in the September quarter of 1978 was being sustained at a daily rate of some 0.71 million cubic metres per day (25.0 million cu. ft/day).

In late 1969, Adelaide received natural gas through the 22 inch 778 km pipeline from the Gidgealpa - Moomba field. Production through this line was some 5.44 million cubic metres per day (192.2 million cu.ft/day) in the September quarter of 1976 prior to gas being supplied to Sydney. The natural gas line to Sydney from the Cooper Basin fields in South Australia was brought into service in late 1976 with natural gas being supplied to Sydney consumers in late December. Average rate of gas production from the Cooper Basin fields in the September quarter of 1978 was 7.8 million cubic metres/day (277 million cu.ft/day. Natural gas was delivered to the Perth area from the Dongara field in October 1971 and on the September quarter of 1978 was delivering gas at a rate of 2.29 million cubic metres per day (81.0 million cu.ft/day).

In 1977 indigenous crude oil production from proven fields supplied about 68.7% of Australia's requirements. However, the crude oils discovered so far are deficient in the heavier distillation fractions required by heavy industry and road and paving construction, and thus import of crudes rich in these fractions must continue, at about 30% of total consumption, until an adequate source is found in Australia. Also since national consumption on average is increasing at about 3.8% per year, further substantial Australian discoveries are essential in order to maintain or reduce the deficit gap between indigenous production and importation.

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

THE ROLE OF GOVERNMENT IN ASSISTING MINERAL EXPLORATION AND DEVELOPMENT

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

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

The Commonwealth undertakes all topographic mapping within its own territories and is active in most States. Commonwealth agencies are the Division of National Mapping (Department of National Development), which has the primary responsibility, and the Royal Australian Survey Corps (Army), which does a substantial amount of work. The basic scale of topographical mapping is 1:100 000 with 20-metre contours. For about one half of Australia, the populated areas and the coastal fringe, line maps are to be published at this scale, of which about half are now available. For the central portion, orthophotomaps with 20-m contours will be published at 1:100 000, backed up with line maps at 1:250 000 with 50-m contours, which will eventually cover the whole of Australia, and replace the existing, mainly uncontoured, non-metric 1:250 000 series. There is complete interchange of data between members of the National Mapping Council, both Commonwealth and State, to minimise cost. National Mapping also is undertaking a program of bathymetric mapping of the continental shelf at 1:250 000 (contour interval 20 m) and to date about 23 of the 250 sheets have been printed. Mapping at larger scales is produced by the States, and by the Army for training purposes, and National Mapping maintains a 1:10 000 series of all populated places of more than 250 people, primarily for census collection purposes. The area covered by this larger scale mapping is of course limited. Air photographs of the whole of Australia are also available.

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Both Commonwealth and State agencies undertake regional geological mapping. Programs are agreed upon in consultation between the Bureau of Mineral Resources and the State Geological Surveys, but the work is necessarily a good deal slower than that of topographical mapping and the time required to complete a similar 1:250 000 coverage of the continent is several times as long at least. However, over 90 percent of the continent has been covered since World War II, and mapping is expected to be completed by 1980.

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

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

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

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

- The income tax rate is 46% of taxable income.
- Petroleum miners' exploration expenditure is deductible against income from any source (previously it was deductible only against petroleum income).
- For other mineral exploration there is an immediate deduction of mineral exploration expenditure incurred anywhere in Australia, against income from mining activities only.
- All capital expenditure at the mine site (except exploration expenditure, which is written off immediately as above) of both general mining and petroleum mining can now be written off on a reducing balance basis at the rate of 20% (that is the miner can write off each year 20% of the accumulated capital expenditure remaining after last year's tax, so that after 5 years he will have written of 67% of the total). Previously the rate was 4% per year, so this is a considerable concession. In the case of a mine with an estimated life of 5 years or less he can write off the capital expenditure by annual instalments over the life of the mine.
- For capital expenditure away from the mine site (for transport facilities, for example, or for most port facilities) the capital expenditure can be deducted over 10 years or 20 years at the option of the tax payer.
- The "investment allowance" for new items of equipment (which applies to all industries) is 20% 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% exemption from tax because it was felt that a national need existed to foster their exploration; and gold mining as a special case has been free of income tax since 1924. The 20% exemption from tax for particular minerals has now been removed, but profits from gold mining are still tax free.

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

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

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

CONCLUDING REMARKS

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

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 the accompanying table. Discussions of resources present problems because no realistic estimate of identified resources in Australia is yet available for many of the minerals concerned. For a number of reasons, published figures tend to be minimal and ultra-conservative. The Bureau of Mineral Resources is carrying out more realistic assessments and has completed and published first assessments of identified resources of black coal, of the beach sand minerals, tin, iron ore, tungsten and antimony; a detailed reassessment of tin resources and assessment of chromium resources are under way and those for other minerals will follow in due course. For the purpose of this report identified resources have been classified under general categories likely to be significant in terms of industrial mobilisation. These categories are based on the expected life of known resources at current rates of production and are defined as follows:

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

In some cases, the uncertainty of reserves is indicated.

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

TABLE 1. VALUE OF EXPORTS BY INDUSTRIAL GROUPS

	1973/74		1974/75		1975/76		1976/77		1977/78 (a)	
	Value (f.o.b. $'000)	%	Value (f.o.b. $'000)	%	Value (f.o.b. $'000)	%	Value (f.o.b. $'000)	%	Value (f.o.b. $'000)	%
Industrial Groups -										
Agriculture	1 112 395	16.7	2 257 736	27.0	2 105 953	22.7	2 137 168	18.8	2 057 454	17.3
Pastoral -										
Wool	1 156 564	17.3	753 492	9.0	961 979	10.4	1 477 000	13.0	1 183 358	9.9
Other	1 023 457	15.3	626 700	7.5	913 276	9.9	1 304 414	11.5	1 629 406	13.7
Dairy and farmyard	165 042	2.5	173 896	2.1	212 971	2.3	204 462	1.8	209 485	1.8
Mines and quarries (other than gold) (b)	1 563 608	23.4	2 253 595	26.9	2 651 741	28.6	3 420 050	30.0	3 580 222	30.1
Fisheries	68 941	1.0	71 331	0.9	83 474	0.9	143 762	1.2	152 838	1.3
Forestry	11 058	0.2	12 085	0.1	11 674	0.1	12 432	0.1	13 047	0.1
Total Primary Produce	5 101 568	76.5	6 148 336	73.5	6 941 063	74.9	8 699 288	76.4	8 825 810	74.2
Manufactures	1 380 504	20.7	1 933 341	23.1	1 991 517	21.5	2 364 329	20.8	2 679 975	22.5
Refined petroleum oils	100 817	1.5	157 443	1.9	159 636	1.7	200 299	1.8	232 046	1.9
Unclassified	89 963	1.3	128 135	1.5	173 546	1.9	112 436	1.0	160 071	1.4
Total Australian Produce	6 672 852	100.0	8 367 756	100.0	9 265 766	100.0	11 376 352	100.0	11 897 902	100.0

(a) Preliminary (b) Value of gold included for 1976-77 and 1977-78.

TABLE 2 SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

1978

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

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SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

	Availability of Supply			Mineral Processing			
Metal or Mineral	Distribution	Domestic Identified Resources	Current Raw material Imports	Level of Processing	Distribution	Current Imports	Possible Disadvantages in Emergency
Non-Ferrous							
Tin	Well distributed Major - Tasmania	Adequate	-	Concentrates and metal	Metal - Sydney only.	Minor tin-plate	Major deposits off mainland (Tasmania) Only one smelter
Lead	Well distributed - mainly eastern Australia	Large	-	Concentrates, bullion and metal	Metal - NSW, SA	-	-
Zinc	Well distributed - mainly eastern Australia	Large	-	Concentrates, metal	Metal - Tas, NSW, SA	-	-
Copper	Well distributed - mainly eastern Australia	Adequate	-	Concentrates, blister, metal	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 and minor combined rare earths for polishing.	Eastern Aust.	-	Could produce rare earths.

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

	Availability of Supply				Mineral Processing			
Metal or Mineral	Distribution	Domestic Identified Resources	Current Raw material Imports	Level of Processing	Distribution	Current Imports	Possible Disadvantages in Emergency
Light Metals							
Aluminium	Northern and SW Australia	Very large	-	Alumina, metal	Metal - NSW, Vic, Tas.	Minor shapes	Major resources N. Aust. Alumina Qld. & WA remote from smelters
Magnesium	Well distributed (magnesite)	Adequate	About 60% magnesite imported	No metal produced	-	All metal	Metal can be produced as in World War II
Fuels							
Coal	Eastern Australia mainly	Very large	Some high quality anthracite	Coke, coal gas, char	Coke-Qld, NSW, SA, Char - Vic. WA	Petroleum Coke	No chemical plants
Petroleum	Well distributed	Inadequate - self-sufficiency in 1978 about 70%	About 30% of requirement - crude and refined products	Refinery products	Well distributed	Some refinery products, heavy crudes	Major supplies offshore. Import of heavy crudes
Uranium	Northern Australia, WA, SA	Large	-	U_3O_8 (yellow cake) radio-isotopes	Northern Australia Sydney	Radio-isotopes	Reserves widespread but current plant in Qld. Others planned.
Chemical Fertilisers							
Phosphorus (Phosphate rock)	NW Qld, NT	Very large	All requirements	-	Fertiliser made in all States	Some mixed fertilisers	Domestic resources 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	Well distributed	Some chlorine, 70% caustic soda requirements.	

SUMMARY OF AUSTRALIAN MINERAL INDUSTRY

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

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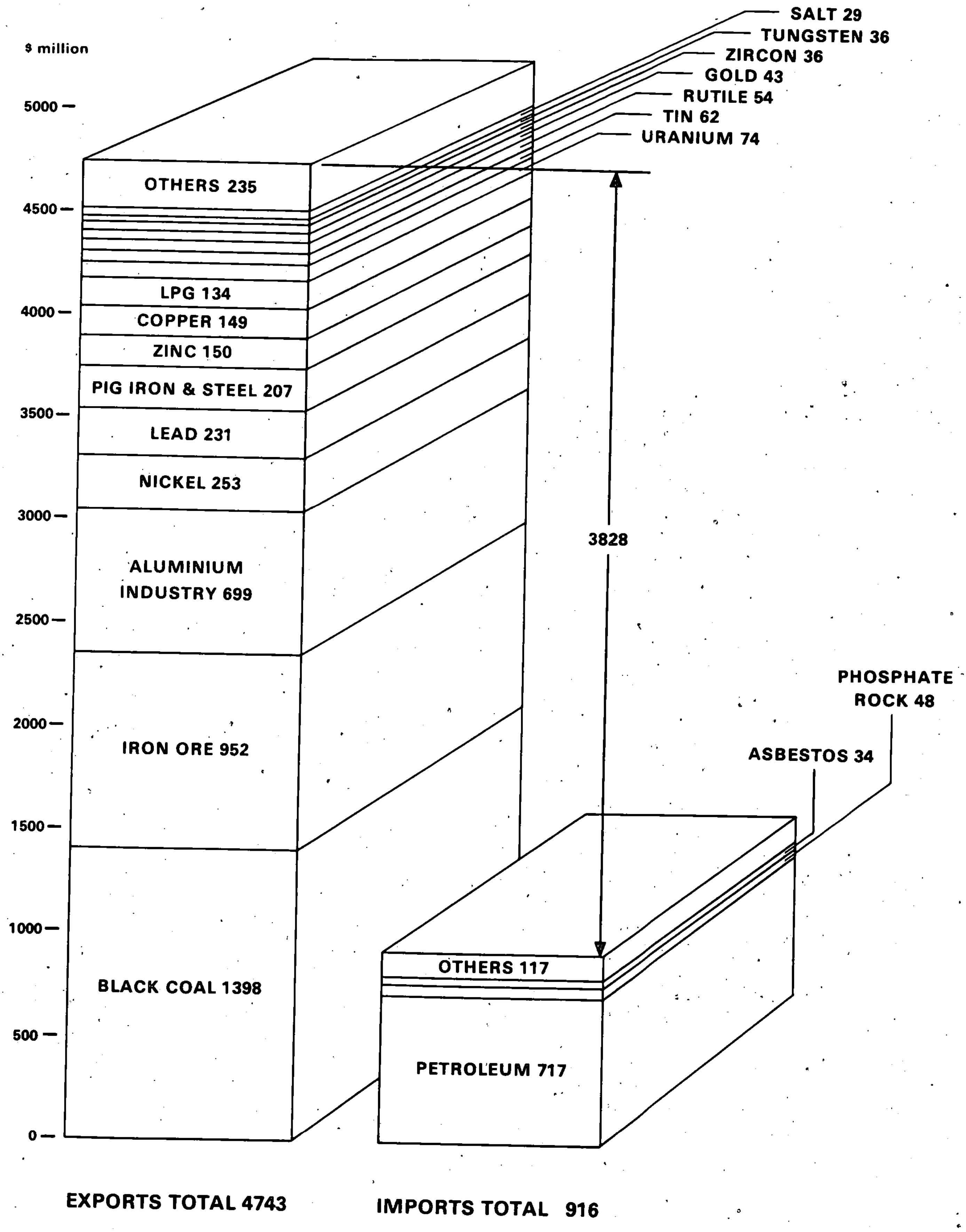

Figure 1. Mineral sufficiency in Australia: values of exports and imports.

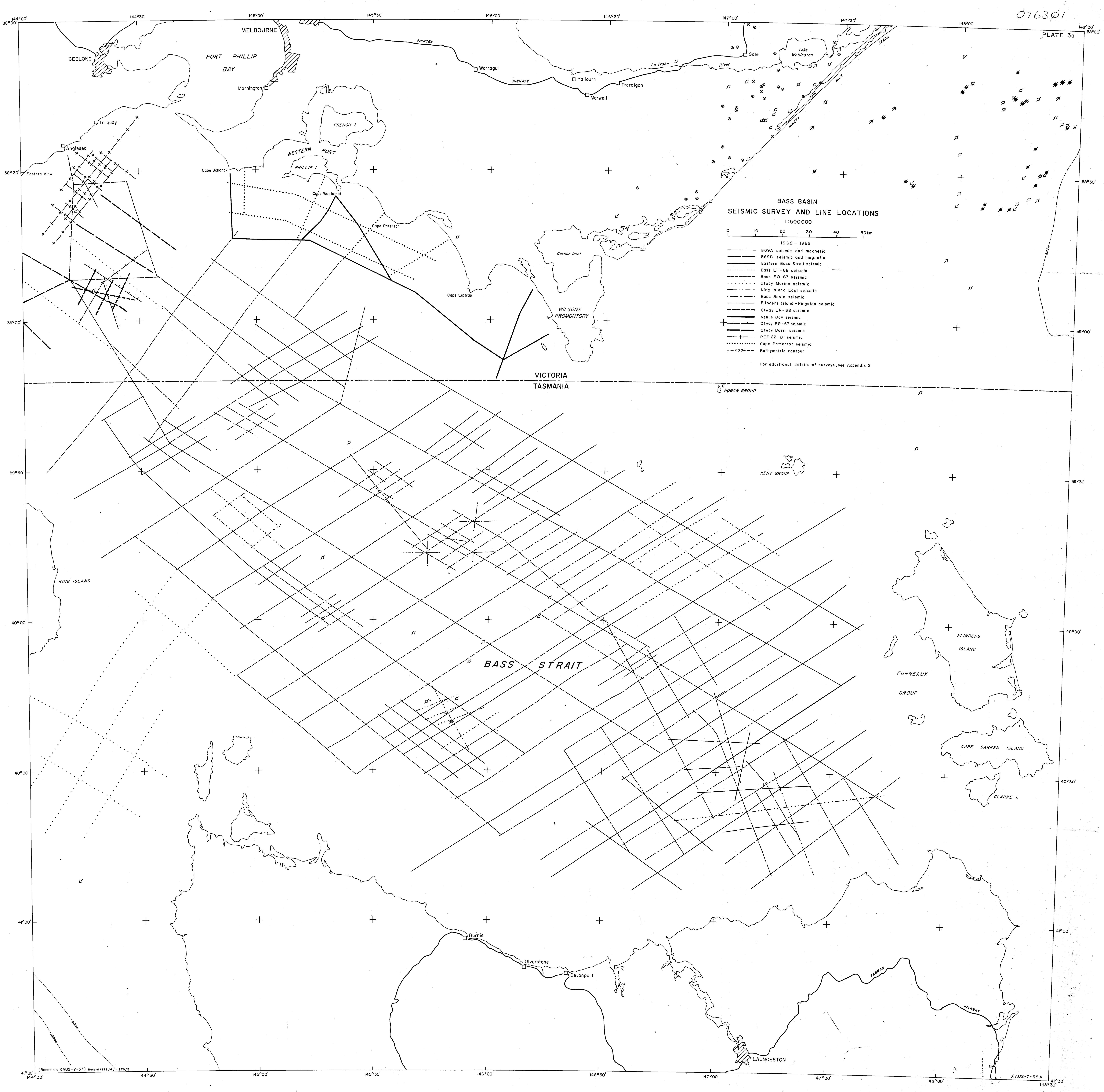
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PLATE 3a
BASS BASIN
SEISMIC SURVEY AND LINE LOCATIONS
1:500000
0 10 20 30 40 50km
1962 – 1969
B69A seismic and magnetic
B69B seismic and magnetic
Eastern Bass Strait seismic
Bass EF-68 seismic
Bass ED-67 seismic
Otway Marine seismic
King Island East seismic
Bass Basin seismic
Flinders Island – Kingston seismic
Otway ER-68 seismic
Venus Bay seismic
Otway EP-67 seismic
Otway Basin seismic
PEP 22-D1 seismic
Cape Patterson seismic
200m Bathymetric contour
For additional details of surveys, see Appendix 2
MELBOURNE
GEELONG
PORT PHILLIP BAY
Mornington
Torquay
Anglesea
Eastern View
Cape Schanck
WESTERN PORT
PHILLIP I.
FRENCH I.
Cape Woolamai
Cape Paterson
Cape Liptrap
Corner Inlet
WILSONS PROMONTORY
Warragul
Yallourn
Morwell
Traralgon
Sale
Lake Wellington
PRINCES HIGHWAY
La Trobe River
NINETY MILE BEACH
VICTORIA
TASMANIA
HOGAN GROUP
KENT GROUP
KING ISLAND
BASS STRAIT
FLINDERS ISLAND
FURNEAUX GROUP
CAPE BARREN ISLAND
CLARKE I.
Burnie
Ulverstone
Devonport
LAUNCESTON
TASMAN HIGHWAY
(Based on XAUS-7-57) Record 1979/4, 1979/5
XAUS-7-98A

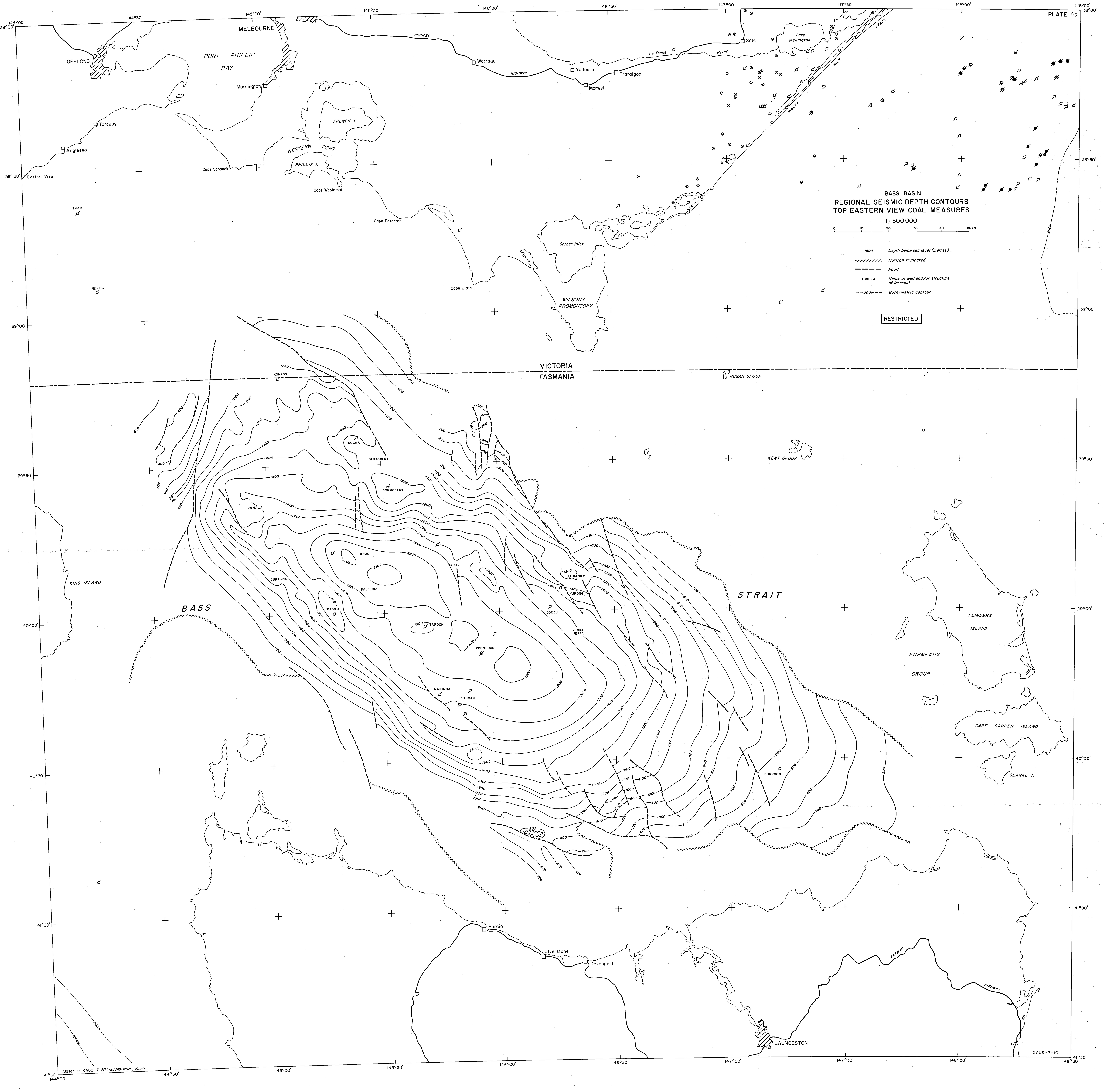
PLATE 4a
BASS BASIN
REGIONAL SEISMIC DEPTH CONTOURS
TOP EASTERN VIEW COAL MEASURES
1:500 000
Depth below sea level (metres)
Horizon truncated
Fault
Name of well and/or structure of interest
Bathymetric contour
RESTRICTED
MELBOURNE
GEELONG
PORT PHILLIP BAY
Mornington
Torquay
Anglesea
Eastern View
Cape Schanck
WESTERN PORT
FRENCH I.
PHILLIP I.
Cape Woolamai
Cape Paterson
Cape Liptrap
Corner Inlet
WILSONS PROMONTORY
Warragul
Yallourn
Morwell
Traralgon
Sale
Lake Wellington
La Trobe
River
PRINCES
HIGHWAY
NINETY MILE BEACH
SNAIL
NERITA
VICTORIA
TASMANIA
KONKON
HOGAN GROUP
TOOLKA
KURRAWERA
CORMORANT
DAMALA
ANDO
CURRINGA
KALPERRI
PAPAN
BASS 3
TAROOK
POONBOON
BASS 2
YURONGI
DONDU
JERRA JERRA
NARIMBA
PELICAN
DURROON
KENT GROUP
KING ISLAND
BASS
STRAIT
FLINDERS ISLAND
FURNEAUX GROUP
CAPE BARREN ISLAND
CLARKE I.
Burnie
Ulverstone
Devonport
LAUNCESTON
TASMAN
HIGHWAY
XAUS-7-101

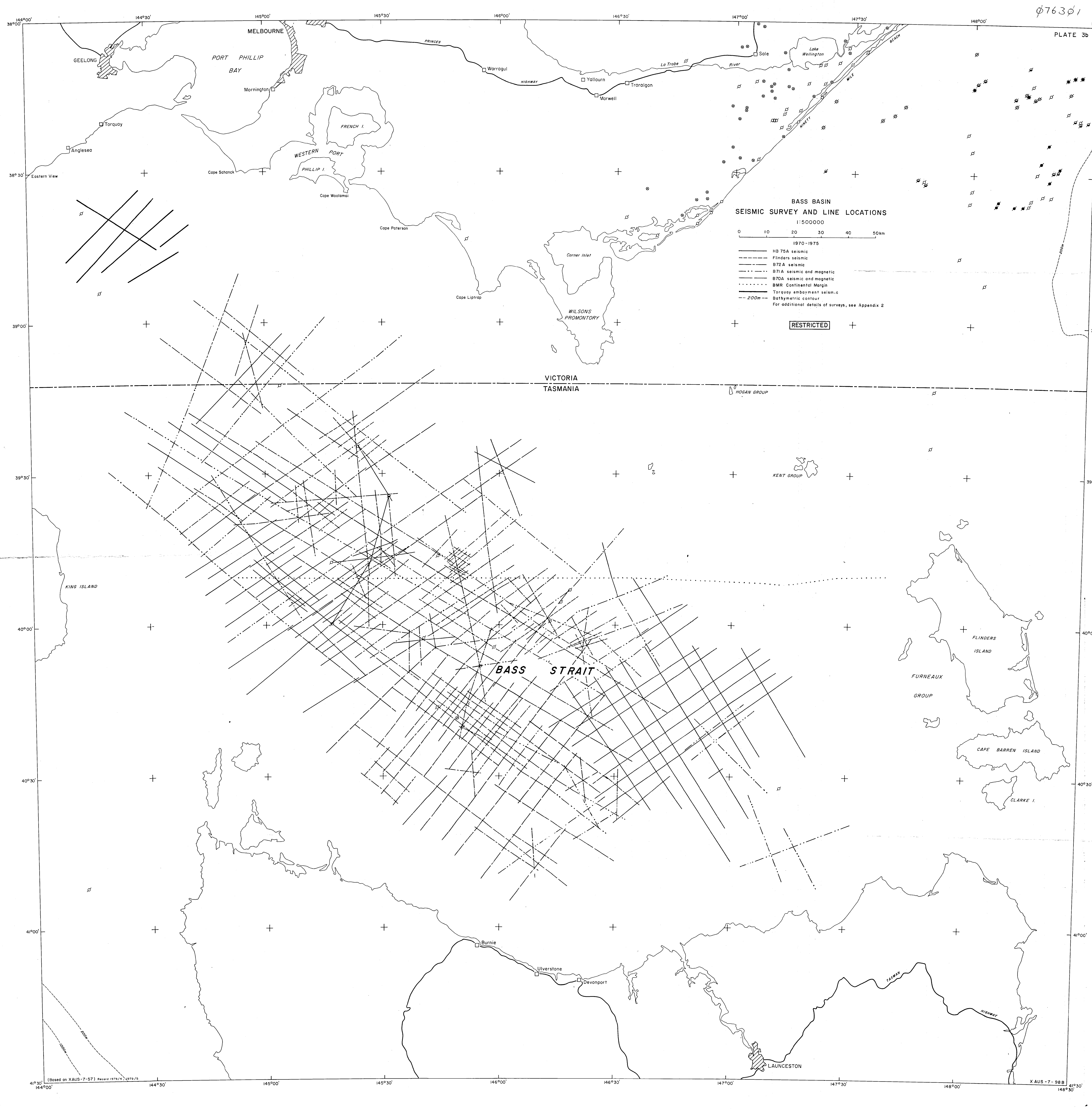
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PLATE 3b
BASS BASIN
SEISMIC SURVEY AND LINE LOCATIONS
1:500000
0 10 20 30 40 50km
1970-1975
HB 75A seismic
Flinders seismic
B72A seismic
B71A seismic and magnetic
B70A seismic and magnetic
BMR Continental Margin
Torquay embayment seismic
200m Bathymetric contour
For additional details of surveys, see Appendix 2
RESTRICTED
MELBOURNE
GEELONG
PORT PHILLIP BAY
Mornington
Torquay
Anglesea
Eastern View
Cape Schanck
WESTERN PORT
FRENCH I.
PHILLIP I.
Cape Woolamai
Cape Paterson
Cape Liptrap
Corner Inlet
WILSONS PROMONTORY
Warragul
Yallourn
Morwell
Traralgon
Sale
Lake Wellington
La Trobe River
PRINCES HIGHWAY
NINETY MILE BEACH
VICTORIA
TASMANIA
HOGAN GROUP
KENT GROUP
KING ISLAND
BASS STRAIT
FLINDERS ISLAND
FURNEAUX GROUP
CAPE BARREN ISLAND
CLARKE I.
Burnie
Ulverstone
Devonport
LAUNCESTON
TASMAN HIGHWAY
200m
1000m
144°00'
144°30'
145°00'
145°30'
146°00'
146°30'
147°00'
147°30'
148°00'
148°30'
38°00'
38°30'
39°00'
39°30'
40°00'
40°30'
41°00'
41°30'
(Based on XAUS-7-57) Record 1979/4, 1979/5
X AUS-7-98B

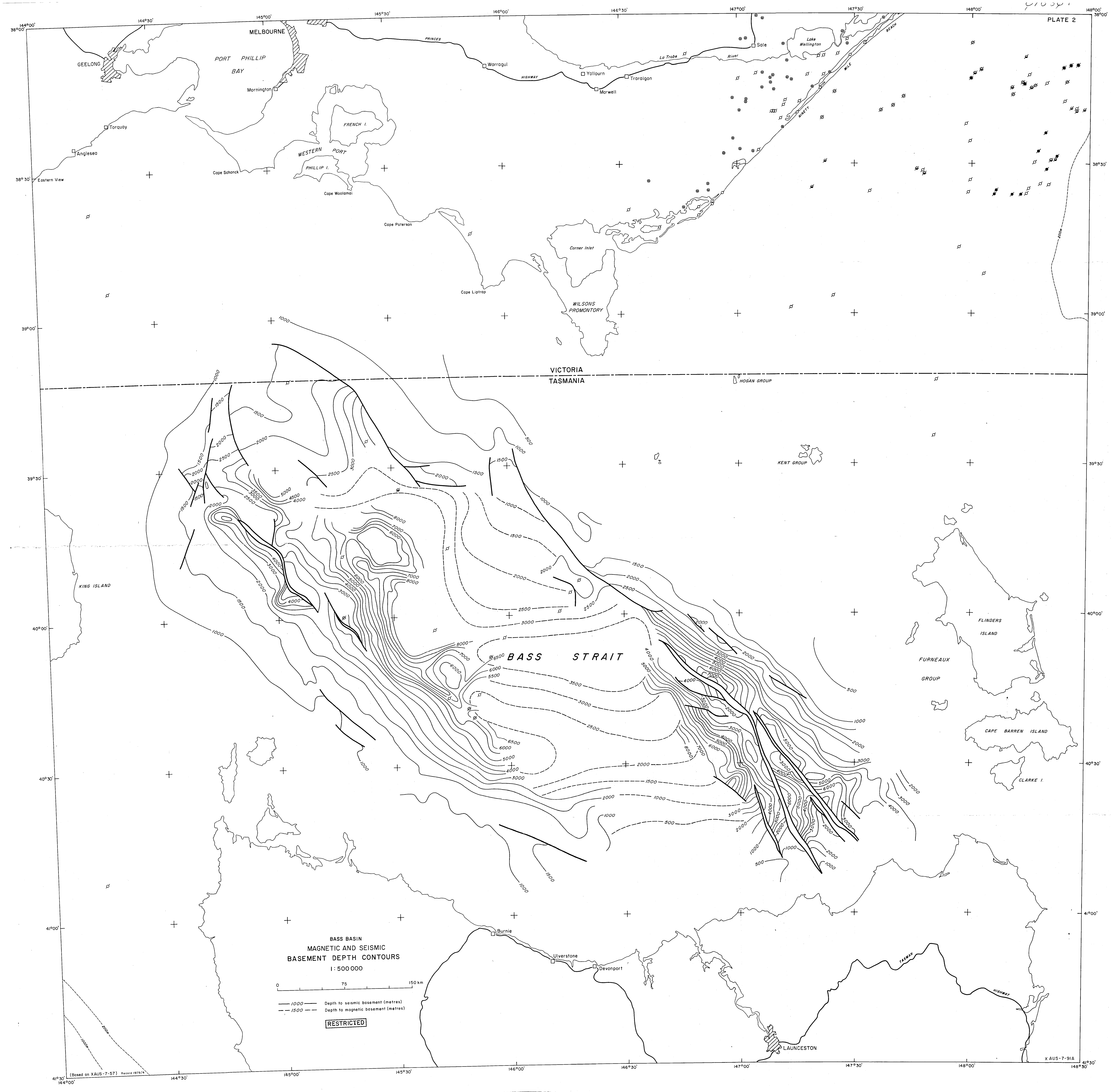
PLATE 2
MELBOURNE
GEELONG
PORT PHILLIP BAY
Mornington
Torquay
Anglesea
Eastern View
Cape Schanck
WESTERN PORT
FRENCH I.
PHILLIP I.
Cape Woolamai
Cape Paterson
Cape Liptrap
Corner Inlet
WILSONS PROMONTORY
Warragul
Yallourn
Morwell
Traralgon
Sale
Lake Wellington
PRINCES HIGHWAY
La Trobe River
NINETY MILE BEACH
VICTORIA
TASMANIA
HOGAN GROUP
KENT GROUP
KING ISLAND
BASS STRAIT
FLINDERS ISLAND
FURNEAUX GROUP
CAPE BARREN ISLAND
CLARKE I.
Burnie
Ulverstone
Devonport
LAUNCESTON
TASMAN HIGHWAY
BASS BASIN
MAGNETIC AND SEISMIC
BASEMENT DEPTH CONTOURS
1:500 000
0 75 150 km
1000 Depth to seismic basement (metres)
1500 Depth to magnetic basement (metres)
RESTRICTED
(Based on XAUS-7-57) Record 1979/4
X AUS-7-91A
144°00'
144°30'
145°00'
145°30'
146°00'
146°30'
147°00'
147°30'
148°00'
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38°00'
38°30'
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41°00'
41°30'

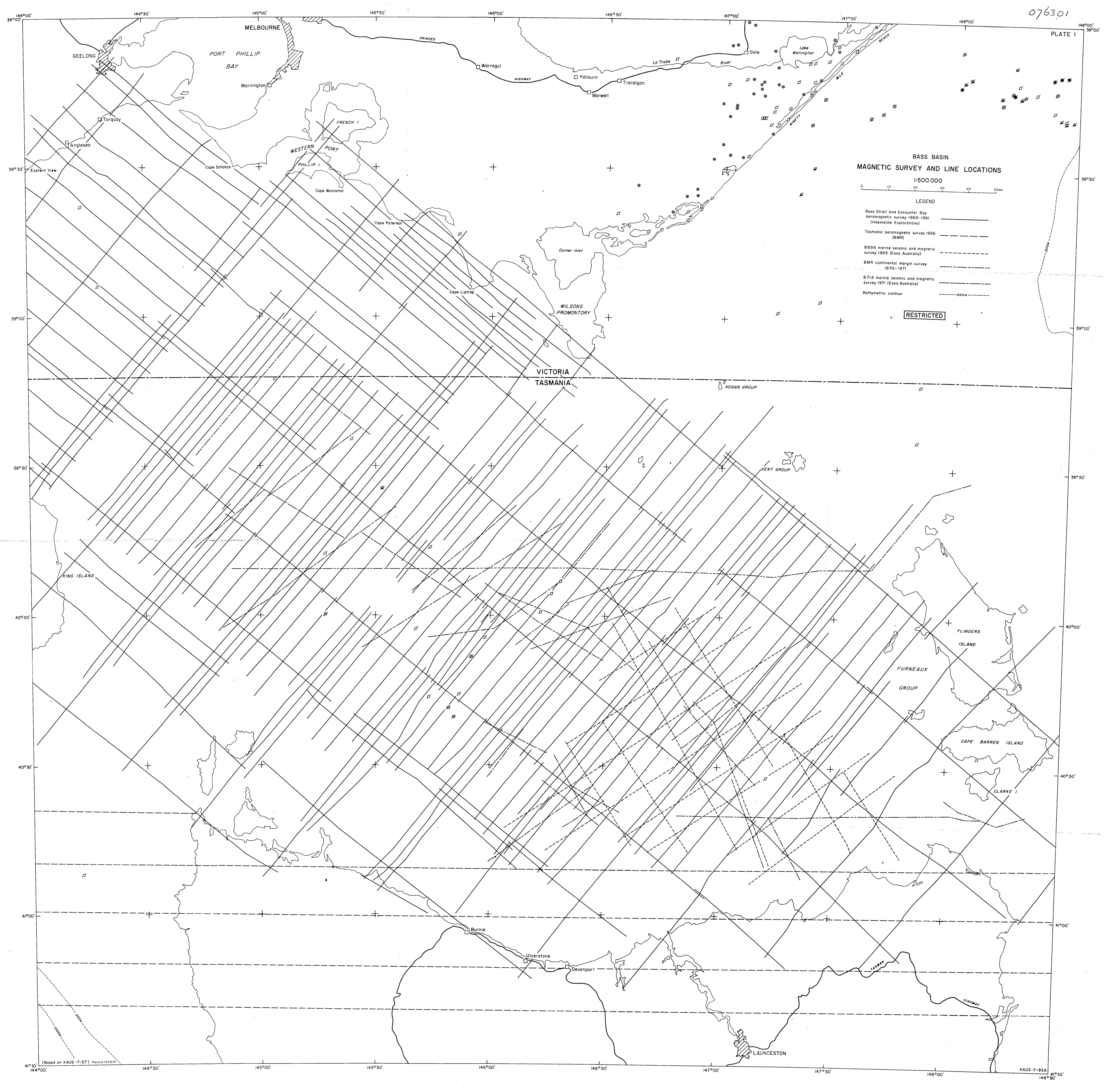
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PLATE 1
BASS BASIN
MAGNETIC SURVEY AND LINE LOCATIONS
1:500 000
0 10 20 30 40 50km
LEGEND
Bass Strait and Encounter Bay aeromagnetic survey 1960-1961 (Haematite Explorations)
Tasmania aeromagnetic survey 1966 (BMR)
B69A marine seismic and magnetic survey 1969 (Esso Australia)
BMR continental margin survey 1970-1971
B71A marine seismic and magnetic survey 1971 (Esso Australia)
Bathymetric contour
200m
RESTRICTED
MELBOURNE
GEELONG
PORT PHILLIP BAY
Mornington
Torquay
Anglesea
Eastern View
Cape Schanck
WESTERN PORT
FRENCH I.
PHILLIP I.
Cape Woolamai
Cape Paterson
Cape Liptrap
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TASMANIA
HOGAN GROUP
KENT GROUP
KING ISLAND
FLINDERS ISLAND
FURNEAUX GROUP
CAPE BARREN ISLAND
CLARKE I.
Burnie
Ulverstone
Devonport
TASMAN HIGHWAY
LAUNCESTON
1000m
(Based on XAUS-7-57) Record 1979/4
XAUS-7-93A
38°00'
38°30'
39°00'
39°30'
40°00'
40°30'
41°00'
41°30'
144°00'
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145°00'
145°30'
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148°00'
148°30'

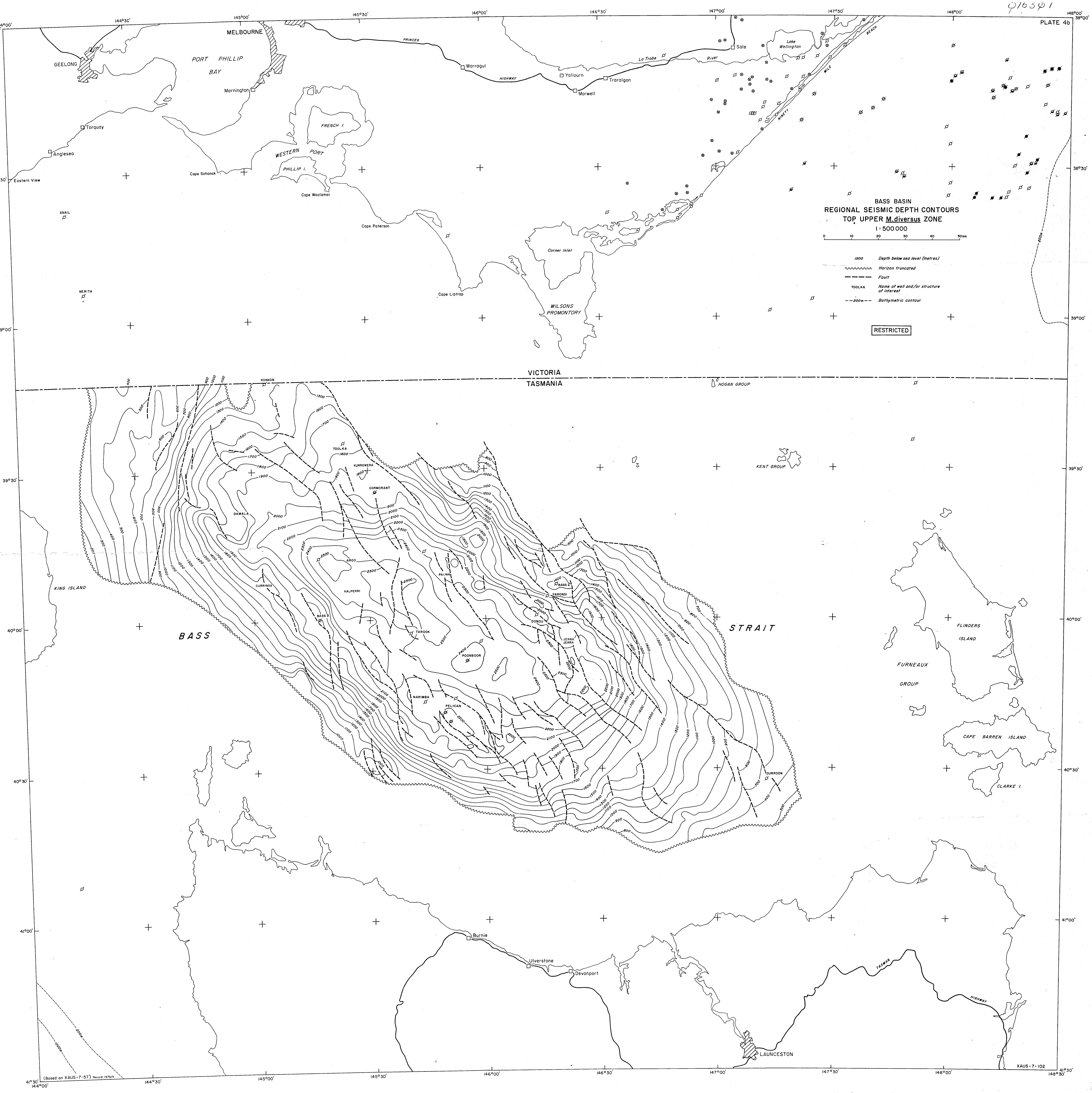
PLATE 4b
BASS BASIN
REGIONAL SEISMIC DEPTH CONTOURS
TOP UPPER M.diversus ZONE
1:500 000
1500 Depth below sea level (metres)
Horizon truncated
Fault
TOOLKA Name of well and/or structure of interest
200m Bathymetric contour
RESTRICTED
MELBOURNE
GEELONG
PORT PHILLIP BAY
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Torquay
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Eastern View
WESTERN PORT
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Traralgon
Sale
Lake Wellington
PRINCES HIGHWAY
La Trobe River
NINETY MILE BEACH
SNAIL
NERITA
VICTORIA
TASMANIA
KONKON
HOGAN GROUP
TOOLKA
KURROWERA
CORMORANT
DAMALA
ARGO
PALTAR
BASS
YARONGI
CURRINGA
KALPERRI
BASS 3
TAROOK
DONDU
JENNA JEARA
POONBOON
NARIMBA
PELICAN
KENT GROUP
KING ISLAND
BASS
STRAIT
FLINDERS ISLAND
FURNEAUX GROUP
CAPE BARREN ISLAND
CLARKE I.
DUCROON
Burnie
Ulverstone
Devonport
LAUNCESTON
TASMAN HIGHWAY
XAUS-7-102
(Based on XAUS-7-57) Record 1975/6

Publication	Borrower	Date
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