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HISTORICAL DEVELOPMENT OF THE AUSTRALIAN MINERAL INDUSTRY

by

I.R. MCLEOD

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Introduction

The history of the Australian mineral industry began with the first European settlement when the settlers quarried stone and dug clay for bricks for their buildings. The industry since then has had its booms and depressions, but from the discovery of gold at least, it has been an important contributor to the Australian economy. It provides the nation's basic industrial requirements - construction materials, fuel, and industrial raw materials; it has facilitated decentralisation of both population and industry, as towns, railways and ports were established to serve the mines and smelters; it has encouraged technological advancement, both in its own and other, unrelated, fields; and it has been a major earner of export income.

The industry has created wealth for the nation and its people through the discovery and mining of mineral deposits and processing the ore. It now produces some 65 different mineral commodities with an annual value of mine production ranging up to more than \$5 000 million (for coal). Australia is one of the world's leading miners of bauxite (the ore of aluminium), diamonds, gold, iron ore, lead, manganese ore, nickel, titanium (rutile and ilmenite), tungsten, zinc and zircon. It mines, or has unworked deposits of, almost all mineral commodities - of the major mineral raw materials it now lacks only sulphur. Some commodities, such as petroleum and aluminium, have had a relatively short production history in Australia; others, such as the base metals, iron ore, and, especially, coal, go back to the early days of the industry.

Coal

It is not surprising that coal was the first mineral, other than those used for construction, to be found, because seams crop out along the coast to the north and south of Sydney. Coal was first discovered in the Newcastle area by escaped convicts in 1791. Mining began near Newcastle in 1799, and in 1800 coal became the first mineral exported from Australia.

Production increased steadily from the 1830s onwards, and in the mid 1920s Australian production was almost 14Mt, but the depression of the 1930s saw it fall by over a third of this amount. Renewed growth faltered in the

late 1940s. Exports, which normally exceeded 1Mt/year until the mid 1920s, had fallen to about 50 000t by the late 1940s because of increasing competition. At that time also, petroleum products began to replace coal used in industry and railways, and these trends were exacerbated by prolonged industrial unrest in the industry.

It was widely agreed then that coal would be of diminishing importance as a major mineral commodity. However, measures taken to improve the efficiency of mining, realisation of the economic importance of near-surface seams in the Bowen Basin in Queensland, and the emergence of large markets for coking coal in Japan particularly, brought about a resurgence in the coal industry. Exports began to increase rapidly in the mid 1950s, and, with impetus added by the oil shocks of the 1970s, Australia became the world's largest coal exporter, with exports reaching 88Mt in 1985.

The pattern of production changed also. In 1950, New South Wales provided three-quarters of the total production and Queensland 14%. In 1985, the two states provided 47% and 49% respectively, and exports from the two were about equal, 68% of the total Australian production being exported. Despite its changing fortunes, the coal industry had been a major sector of the mineral industry for 150 years. The rapid increase in exports in the 1960s consolidated its pre-eminence: in 1985 coal contributed 24% of the total value of ex-mine production in Australia, represented about a third of the industry's total assets, and provided 16% of total Australian merchandise exports.

Mineral discoveries

Although coal had its ups and downs, the development of the rest of the industry followed an even more chequered course.

In the circumstances at the time, the early settlers were little interested in minerals. Traces of gold were reported from 1823 onwards, and occurrences of other metals were reported from time to time. The first metalliferous mining was of silver-lead, at Glen Osmond near Adelaide, in 1841. Copper mining began at Kapunda, in the same general area, in 1842, and at Burra, to the north, in 1844. At the end of the same decade, the first pig iron was produced from a small deposit of iron ore near Mittagong, NSW.

It was the discovery of payable alluvial gold in 1851 near Bathurst in NSW and, soon after, the rich Victorian fields, that gave impetus to the metalliferous sector of the mineral industry. As search and discovery quickly spread to other parts of eastern Australia, the migrants which the gold attracted, the new communities and new access which resulted, and new emphasis on the mineral potential of the young country all profoundly influenced the development of Australia from the 1850s onwards.

The wealth created by the newly mined gold, and the influx of migrants, began the transition from an agricultural and pastoral economy as industries were established to supply the machinery and transport facilities needed by the mines, and service industries expanded to cater to the increasing population and growing commercial activities.

Three stages can be recognised in the development of the Australian mineral industry after the discovery of gold. The first, from the gold discoveries in 1851 to the end of the nineteenth century, was one of a succession of new discoveries. In the second, to about 1950, few new deposits were found. The third, from then to the present, has been marked by a series of discoveries and developments that changed the industry, and to some extent, the Australian economy, as much as the goldrushes of the 1850s.

Gold was the prospector's prime target for many years after 1851, and the rich Victorian discoveries were followed by many others around the continent, though few were so rich. Many of the new gold-fields were abandoned as the shallow surface alluvials were exhausted, but on some, especially in Victoria, mining progressed to the deep leads - alluvial deposits covered by tens of metres of later sediments or by lava flows.

Prospecting on some fields discovered primary gold lodes rich enough to be worked. But working such lodes required deep shafts and machinery and treatment plants, and these required capital. The individual miner or syndicate was replaced by companies, which employed dozens or even hundreds of men. Towns grew up near the mines, and as confidence in the long life of the mines increased, tents and shanties gave way to more permanent private and commercial buildings. When, decades later, the mines did start to peter out, many such towns survived because they had become centres for the surrounding agricultural and pastoral industries, or were at convenient points on well established transport routes.

The interest in and expertise in prospecting aroused by the gold discoveries soon led to discoveries of other metals. Tin mining began almost simultaneously, in 1872, at Inverell, NSW, Mount Bischoff, Tas, and Stanthorpe, Qld, and with the discovery soon after of other fields, especially Herberton in North Queensland, Australia was the major world source of tin in the late 1870s and early 1880s. Base metals were discovered at many places, including Moonta-Wallaroo, SA, Zeehan-Dundas, Tas, Cobar, NSW, and, beneath gold-rich caps, at Mount Morgan, Qld, and Mount Lyell, NSW. The fabulous Broken Hill lode, whose profits spawned a variety of industries, including steel at Newcastle in 1915, was discovered in 1883.

By the beginning of the twentieth century, the metalliferous mining industry, with associated smelters and refineries, was well established. Gold was still pre-eminent, accounting for three quarters of the total value of metalliferous mine production, with copper, lead and silver accounting for most of the remaining quarter.

Like the goldfields, each mine needed a town for its workers, engineering and machinery suppliers, and transport facilities - including ports to ship its products to other parts of the world. Many towns still alive today owe their foundation to a mineral deposit found in the last four decades of the nineteenth century.

The industry continued to prosper in the early years of the twentieth century. However, it was severely affected by the collapse of metal prices after the ending of World War I. Many mines closed, and the value of mineral exports fell from \$15.3 million in 1919-20 to \$7.6 million in 1921-22.

Few new mineral deposits were found from the beginning of the century until after World War 2; the most notable were lead-zinc-silver and, later, copper at Mount Isa, Qld, gold at Tennant Creek, NT, and tungsten at King Island, Tas.

In the late 1930s the mineral industry, although well established, played a minor role in the Australian economy. It had been particularly successful in opening up the country, had provided coal as fuel in all States, had

bolstered the economy about the turn of the century, and continued to provide, steel, lead, zinc, copper, and tin for Australian secondary industry.

The need for new ore reserves of many minerals was the major concern of the industry in the late 1930s and early 1940s. Indeed, the forty-year drought of new discoveries after the flood of the previous century led some to the belief that there were few new resources to be discovered, and that the industry would gradually run down. The embargo placed on the export of iron ore in 1938, when reserves of high-grade ore were believed to be no more than 260Mt, was a reaction by the Commonwealth Government to this concern.

It is then all the more remarkable that in the late 1940s there began a series of discoveries that was to completely change the structure of the industry and elevate Australia from a minor player in the world mineral scene to a major mineral exporting country. Whereas in the 1950s the mainstays of the industry had been lead, zinc, copper, gold, and coal, and only the first four had been exported in any quantity, Australia by the late 1960s was a world force in aluminium, coal, iron ore, nickel, manganese, titanium, uranium and zirconium as well as the traditional lead and zinc.

The reason for the surge of discoveries is manifold. Some of the 'new' deposits had been known previously, but were not economically workable. The Pilbara iron deposits, 'discovered' in the early 1960s, had been known in the last century - a geologist in 1889 made the prophetic comment "This is essentially an iron country - there is enough to supply the whole world should the present sources be worked out"; and coal had long been known to be widespread in the Bowen Basin in central Queensland. The economics of working such deposits changed remarkably because of technological advances which lowered the cost of mining and transporting huge quantities of material, but these advances would not have been decisive without the emergence of Japan as a major buyer of coal, iron ore and bauxite.

Many discoveries were in fact rediscoveries: new orebodies found close to former mines, eg Cobar, Ardlethan, Cleveland, Mount Gunson, and Koolyanobbing. Their discovery, and the discovery of the many new deposits, was aided by the development of geochemical and geophysical

exploration methods suited to Australian conditions. Many techniques developed in the northern hemisphere were not successful in the arid, deeply weathered terrain characteristic of most of Australia. However, these techniques were modified and new ones developed, and Australia is now a world leader in expertise for mineral exploration in arid regions.

Apart from Japan's economic growth, the expansion of the world economy in the 1950s and 1960s meant an ever increasing demand for minerals. Australia, with its well established industry, had the experience and attitudes needed to find and develop the new deposits needed to meet this demand.

While new technology and expanding demand were essential, it can be questioned whether the flow of new discoveries would have been maintained without the greatly increased knowledge of the geology of Australia which resulted from the systematic geological and geophysical studies by the Bureau of Mineral Resources and the geological surveys of the States. The better understanding of the geological evolution of the continent enabled mineral explorers to search more efficiently by using geological theories on the origin of mineral deposits to target specific areas for concentrated exploration. The better understanding showed also that Australia had a high potential for the discovery of mineral deposits. This realisation, together with Australia's political stability, led to an influx in the early 1960s of major overseas mining companies who, in addition to increasing exploration expenditure, brought in new expertise and ideas.

The great expansion of mineral production resulting from the successes of the increasing exploration effort is illustrated later in this paper. A less obvious result has been the increasing expertise of the exploration sector of the industry. The search for a variety of minerals in diverse geological conditions has developed a highly experienced mineral exploration industry which has begun exporting its skills to other parts of the world.

Petroleum discoveries

The 1960s saw also the discovery of economic accumulations of what had been Australia's most serious mineral deficiency - petroleum.

Although it had been sought for many years, petroleum (which includes crude oil and natural gas) was a latecomer to the mineral production scene in Australia. However, it has made up for lost time and has become one of our major mineral products in terms of value of production; and in 1985, following a change in government policy on petroleum exports, it was Australia's second most valuable mineral export - a pre-eminence which, however, was short lived.

Hydrocarbons, in the form of crude bitumen, were first recorded by the crew of HMS Beagle in 1839, at the mouth of the Victoria River, near the Western Australia-Northern Territory border.

The first well drilled specifically for petroleum was put down in 1882 at Alfred Flat, in the Coorong area of South Australia. However this well, and several others in the same general area, did not encounter any oil. Minor flows of gas were found in 1885 in holes drilled near Narrabeen during a search for coal, but the gas was never utilised commercially.

In 1900, an artesian water bore at Roma, in Queensland, which was being deepened, encountered natural gas. Gas continued to flow freely from the well and in 1906 it was reticulated for town lighting; however, the flow failed after 10 days. A second well also struck gas, which caught fire, and the well was abandoned. This discovery marks the real beginning of petroleum exploration in Australia. Many wells were drilled subsequently in the Roma region; some encountered small quantities of oil or gas, but it was not until 1960 that commercial quantities of gas began to be found.

Although some geologists were pessimistic about the chances of discovery of petroleum in Australia, the search went on sporadically in other parts of the continent also. Perhaps the most notable attempt was at Lakes Entrance, in eastern Victoria. Artesian water with traces of oil and gas flowed from a bore put down in 1924. Some 50 wells were drilled subsequently, and production by several companies of about 487 000 litres of oil was reported to the Mines Department for the period 1930 to 1941. Later, a vertical shaft was sunk to 352 metres, but efforts to recover commercial quantities of oil were abandoned in 1951.

The first substantial flow of oil was in 1953 from the Rough Range No 1 well, in the northwest of Western Australia. However, a commercial field did not eventuate, and the interest in petroleum exploration aroused by the discovery began to wane.

Because of the economic and strategic advantages of an indigenous supply of petroleum, the Commonwealth Government had encouraged, directly and indirectly, the search for it since soon after World War I. With the increasing importance of petroleum and petroleum products to the Australian economy, the Government in 1957 adopted several measures, including a subsidy for specific approved operations, to encourage petroleum exploration. The subsidy expired in 1974.

These measures did much to re-encourage exploration. Another factor was the growing understanding of the geology of the sedimentary basins; this resulted from the systematic geophysical and geological studies by the Bureau of Mineral Resources (which also introduced seismic surveys) and the state geological surveys, and the more detailed work by companies; and each well drilled, even though it was unsuccessful, was a major contributor to this understanding.

In the 1960s, the long search was at last rewarded. Australia's first commercial oil field was discovered at Moonie, 200 km southeast of Roma, in 1961. A pipeline was built to Brisbane, and commercial production began in 1964.

1964 marked several other important events: the discovery of oil and gas at Barrow Island, Western Australia; of gas in what has become a cluster of oil and gas fields in northeast South Australia and the adjoining part of Queensland; and the most important of all, the discovery of gas some 25 km off the Gippsland coast in Australia's first offshore well. The Gippsland Shelf fields now supply three quarters of the crude oil and nearly half of the natural gas produced in Australia.

The Gippsland Shelf discovery, as well as becoming Australia's main source of oil and gas, also turned attention to Australia's extensive continental shelf, and 1971 saw the discovery of the huge gas fields of the North-West

Shelf which, in addition to supplying Western Australia, will begin to feed one of the world's few liquified natural gas export projects at the end of the 1980s.

The move offshore of petroleum exploration, and the subsequent need for development, raised a jurisdictional question. Under the Australian constitution, the responsibility for mineral (including petroleum) activities rests with the State governments. It was not clear if the States' jurisdiction extended seawards beyond 3 miles from the coast. The problem was circumvented by the Commonwealth and each State enacting identical legislation, which had the effect that the Commonwealth and the relevant State would jointly administer offshore petroleum activities, the State being responsible for day-to-day administration; each would receive a share of the royalties from production. Although the High Court subsequently ruled that the Commonwealth had sole jurisdiction seawards of the low water mark, these arrangements have been substantially retained. Arrangements for minerals other than petroleum have not yet been enacted; to date only a little interest has been shown in these, principally for construction materials, gold and mineral sands.

In the early 1970s, petroleum exploration again began to languish - indications from exploration were that onshore oilfields probably would be small and hence unlikely to be economic. However, the oil shocks of 1973 and 1979, when oil prices increased several-fold, completely changed the economics of the industry. Industry expenditure on exploration increased rapidly, from a low of \$49 million in 1976 to \$948 million in 1982; some known fields, such as Palm Valley and some Bass Strait fields, were developed, and many new fields were discovered, especially in southwest Queensland and the adjoining part of South Australia.

While exploration has been primarily for oil, it has discovered large resources of natural gas. Indeed, indications are that geological conditions in Australia in the past have favoured the formation of gas rather than oil. Natural gas contributed 19% of total Australian energy consumption in 1985.

Most Australian crude oils are 'light', and oil still has to be imported to supply heavy fractions needed for lubricating oils, bitumen etc. In 1985, 96% of Australia's crude oil requirements was met by domestic production.

However, unless major new discoveries are made, Australia's crude oil self-sufficiency will begin to decrease in the latter part of the 1980s as production from some existing fields declines. Natural gas supplies, however, are adequate for many years, although resources are unevenly distributed around the continent.

Twenty years of growth

Although the sequence of new discoveries began in the late 1940s, it was really in the mid 1960s that the Australian mineral industry began the expansion to its present breadth and size, with the growth of the coal, iron ore, aluminium and petroleum sectors.

The value of mine production (Fig. 1) increased from \$542 million in 1965 to \$22 432 million in 1985, and the value of exports of mineral primary products increased from \$308 million to \$15 255 million in the same period. A better indication of the growth of the industry, because it is not influenced by changing commodity prices, is given by the index of mineral output at constant prices (Fig. 2), which increased from 232 in 1965 to 1 359 in 1985, and the index of exports of metals and minerals at constant prices (Fig. 2), which increased from 126 to 1 400. In 1965 the value of exports of mineral products (\$308 million) and the value of imports (\$304 million) were about the same. In 1985, exports (\$15 255 million) exceeded imports (\$2030 million) by \$13 225 million (petroleum remained the main import), and mineral exports made up 47% of all merchandise exports.

The growth in both mine production and exports was accompanied by a change in the relative importance of the various commodities. Fig. 3 shows the decreasing relative importance of mine production of gold (continuing a trend from the beginning of the century) and the base metals, the increasing relative importance of coal, iron ore and "other minerals" (which include nickel and mineral sands), and the emergence of bauxite and petroleum. The relative importance of the minerals exported also changed correspondingly, and the uneven geographical distribution of the new deposits meant that the proportion contributed by each State and the Northern Territory to the total annual value of mine production changed (Fig 4). Export destinations changed also; in 1965, 41% of Australia's mineral exports went to Europe (and 24% of total exports were to the United

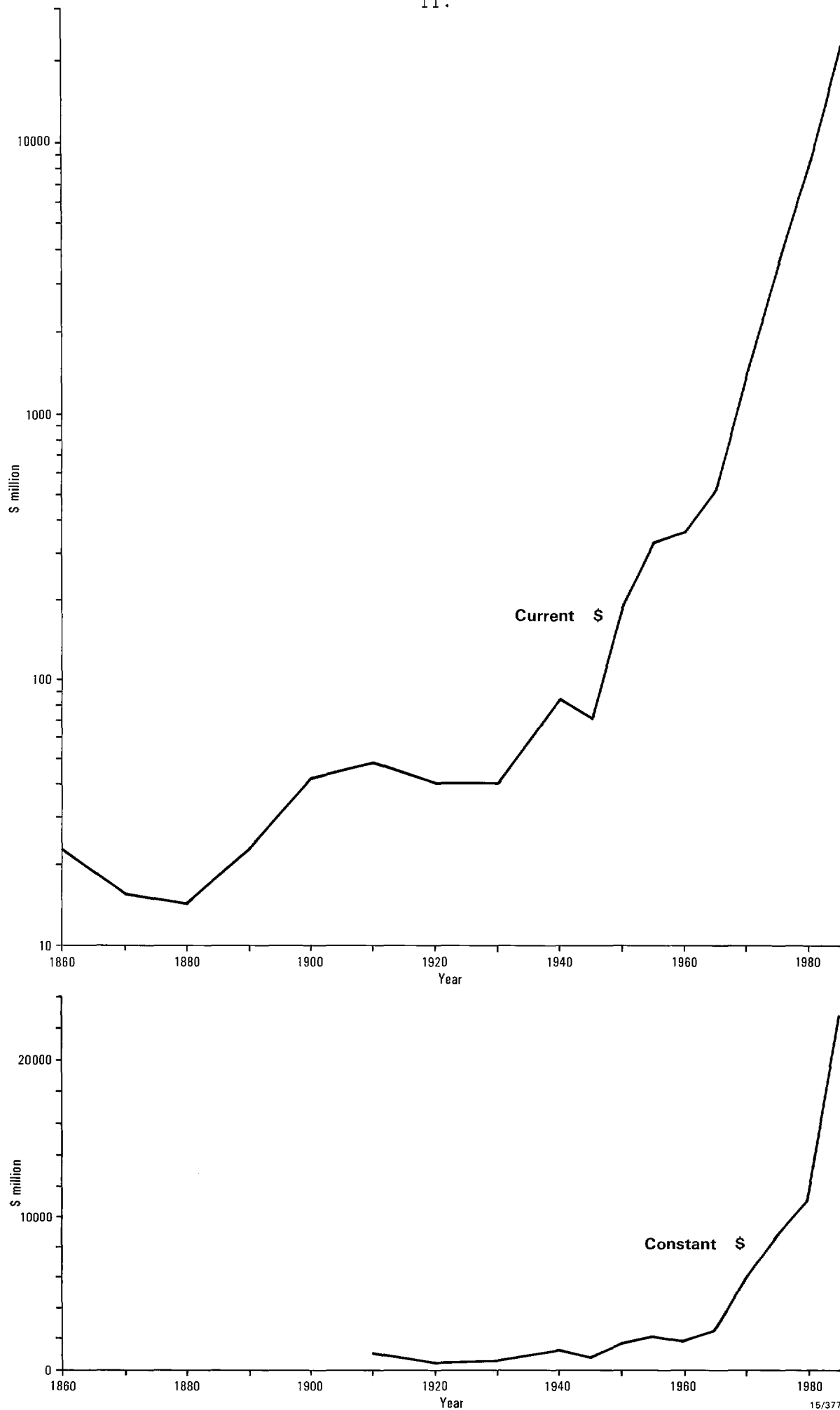


Fig 1 Value of Australian mine production showing value in current dollars, ie dollars of the day (logarithmic scale) and value in constant 1985 dollars, ie dollars of the day converted to equivalent of 1985 dollars using ABS retail price index. Ten year intervals to 1940; five-year intervals thereafter. Estimated in part, especially in earlier years.

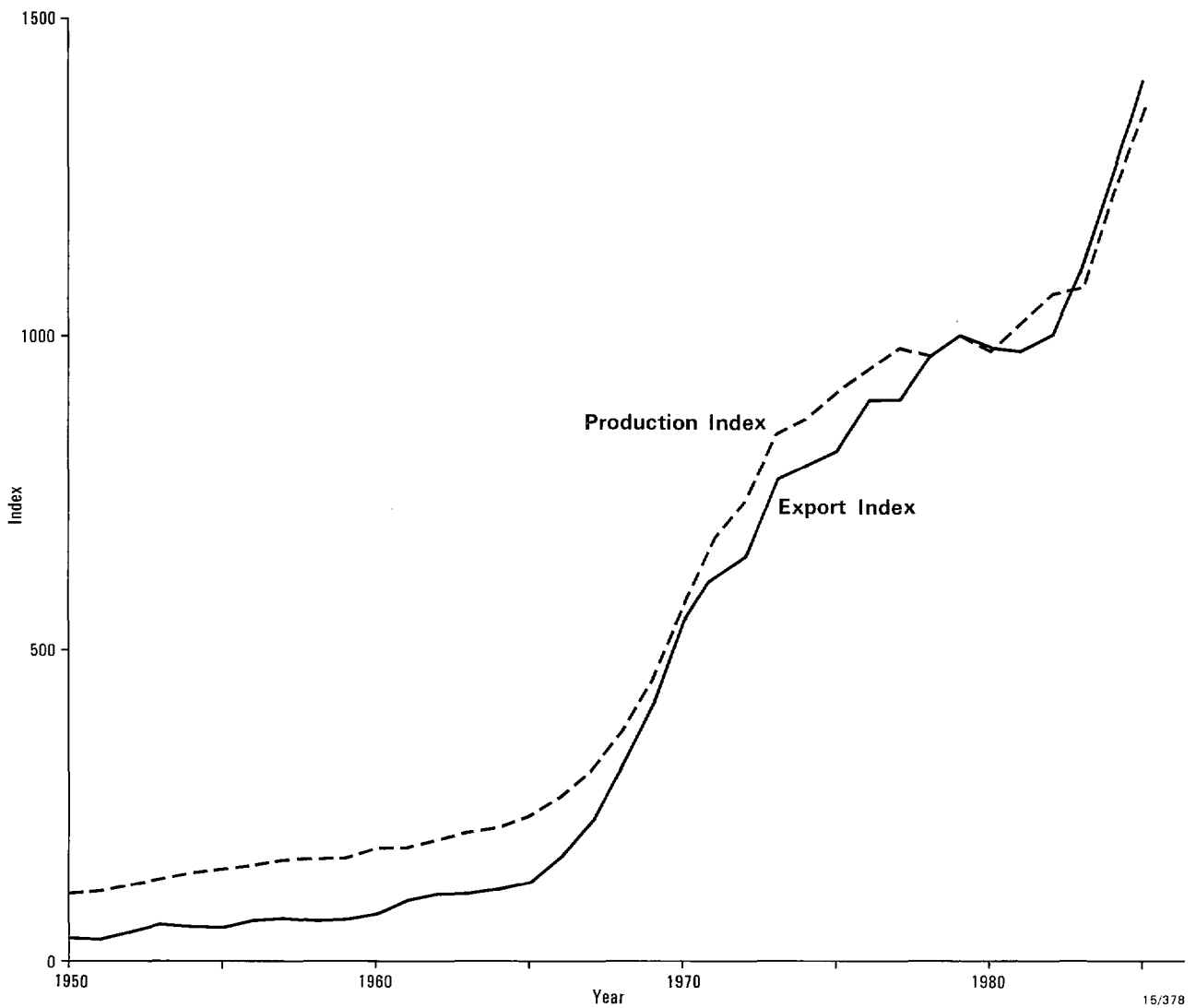


Fig 2 Index of Australian mineral output at constant prices (1979 = 1000) and index of exports of metals and minerals at constant prices (1979 = 1000). Output indices for 1950 to 1972 and export indices for 1950 to 1970 recalculated from early series to current series; data for these years not strictly comparable to data for later years.

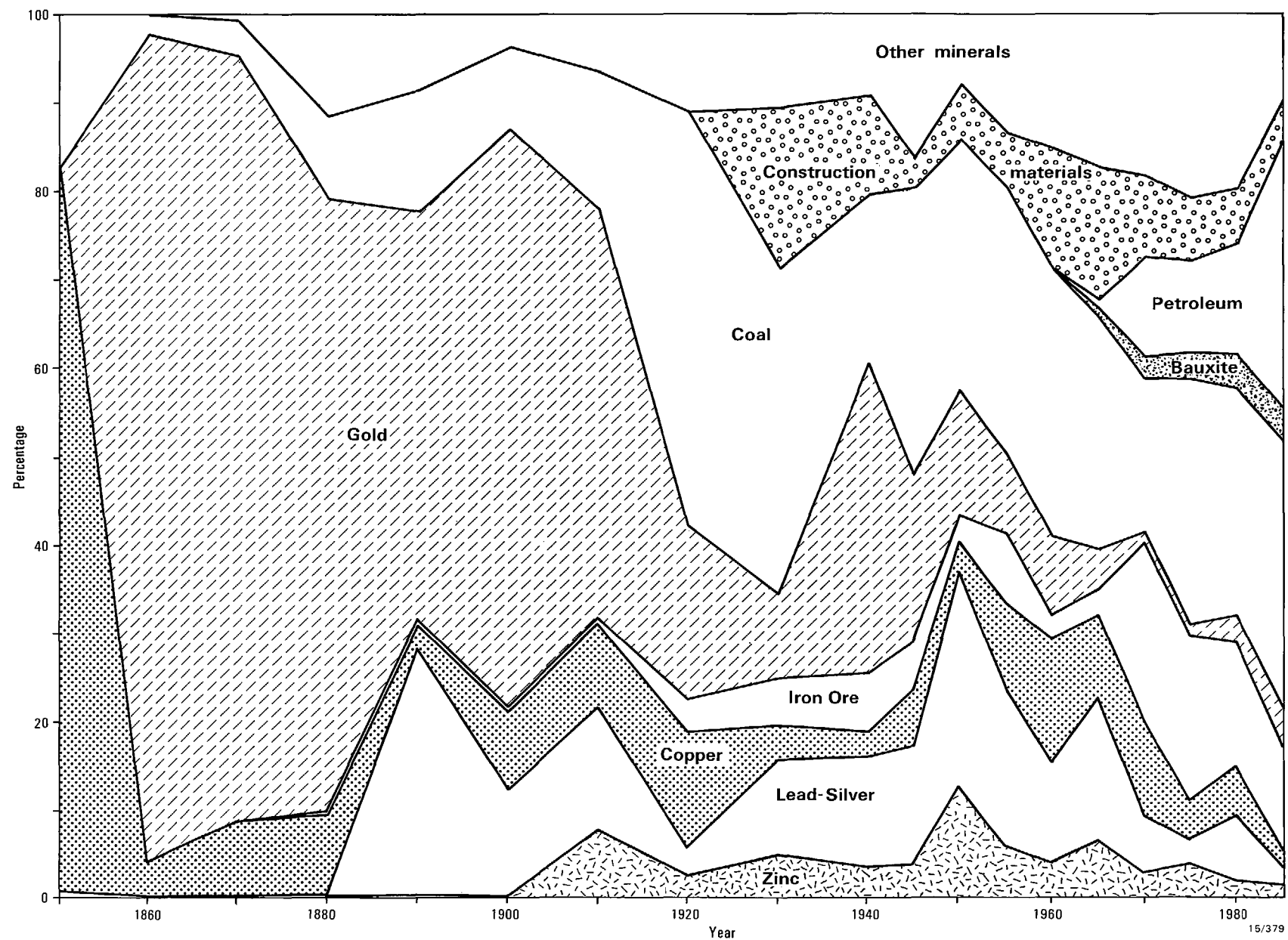


Fig 3 Percentage contribution by major commodities to total annual value of Australian production of minerals. Ten-year intervals to 1940; five-year intervals thereafter. Data estimated in part, particularly in earlier years.

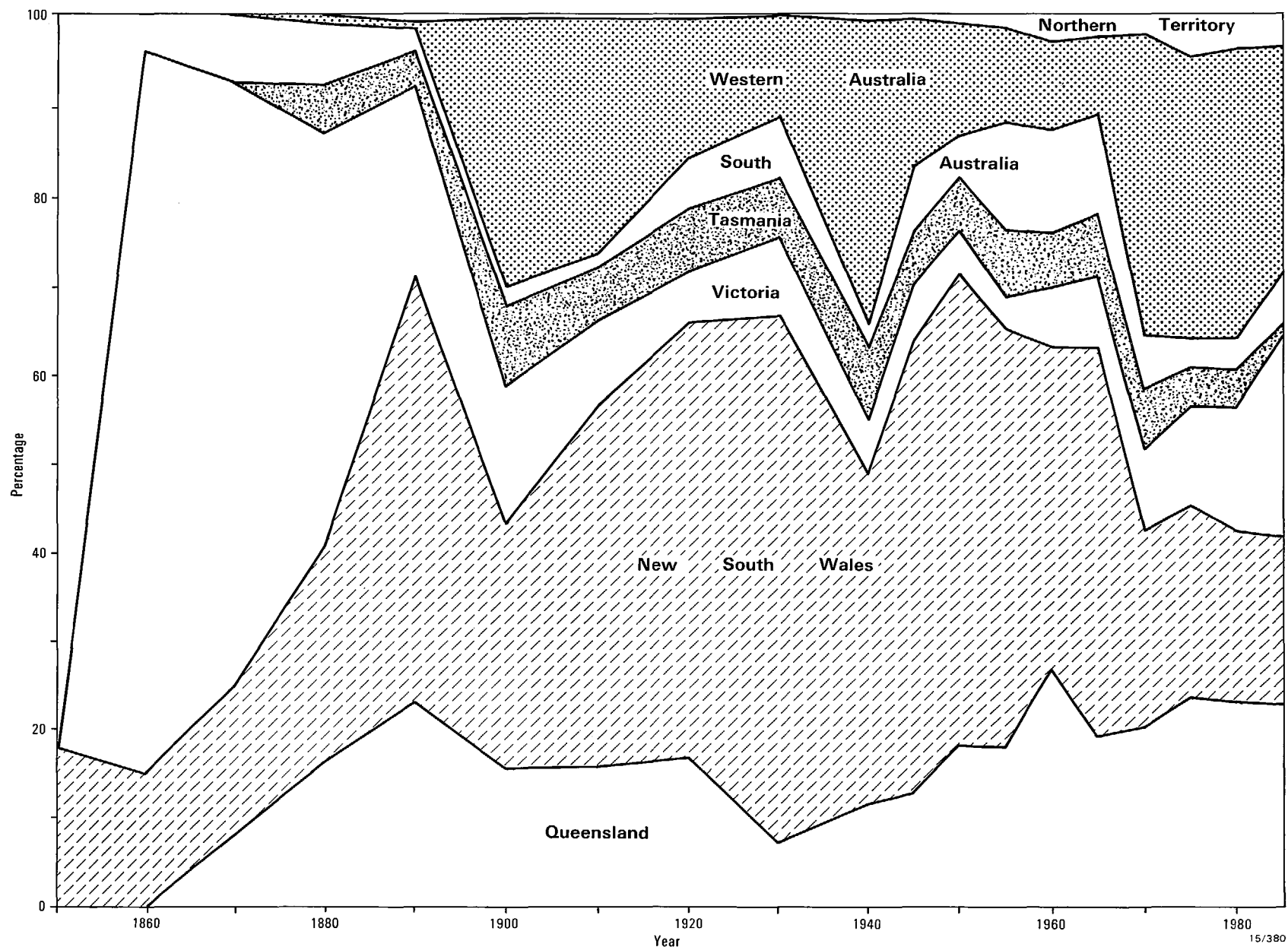


Fig 4 Percentage contribution by States and Northern Territory to total annual value of Australian production of minerals, including petroleum. Ten-year intervals to 1940; five-year intervals thereafter. Data estimated in part, particularly in earlier years.

Kingdom); 41% went to Asia (32% of the total going to Japan); and 16% went to America. In 1985, the corresponding figures were 14% (4%); 63% (41%); and 13%. In 1985 mining and smelting and petroleum production contributed 8% of the Australian GNP, was responsible for 16% of private fixed capital expenditure, and employed 132 000 persons.

Since its early days, the mining industry has processed some of the ores mined to refined metal or intermediate products such as blister copper or lead bullion; and governments have encouraged processing because of its perceived economic advantages. All of the nickel, and much of the bauxite, copper and lead mined is processed to some degree in Australia, as is a smaller part of the output of the other major metals. Except for iron ore and manganese ore, expansion of processing capacity has kept pace with greatly increased mine production of the major metals over the last 20 years; indeed, the proportion of bauxite and ilmenite processed has increased markedly.

In 1965, industry spent \$22 million on mineral exploration, and \$48 million on petroleum exploration. These amounts had increased to peaks of \$576 million and \$948 million in 1981/82 and 1982 respectively. Allowing for inflation (as measured by the retail price index), these peaks represent a multiplication of exploration effort of seven times for minerals and five times for petroleum.

Australian manufacturing industry, despite its growth, could absorb only a small part of the greatly increased mineral production, and consequently the proportion of production exported (in either raw or processed form) increased greatly in the late 1960s and early 1970s. The index of mineral output at constant prices for 1985 was almost 6 times that for 1965, while the index of exports of metals and minerals at constant prices was over 11 times the 1965 figure. Australia is now the world's first, second or third largest exporter of about 10 mineral commodities (including alumina, coal, iron ore, lead, nickel, mineral sands - rutile, ilmenite and zircon - and zinc) and a major exporter of many others.

These exports relieved the pressure on the Australian balance of payments, allowing the economy to grow at a reasonable rate. However, the industry became dependent on exports and so, in turn, on the health of the world economy; it also had to compete with other mineral producing countries to sell its output.

This dependence had an adverse effect in the early 1980s. Lower mineral prices resulting from decreased world demand for minerals, combined with surplus production capacity, caused a drastic decline in the Australian industry's profitability, which was only 2.2% of shareholders funds in 1981/82. Measures to increase efficiency, including increased throughput to lower unit costs, mining higher grade ores, work-force reductions and changed work practices, and, in a number of cases, mine closures, had their effect, and by 1985/86 the return on shareholders funds had increased to 4.9%.

As might be expected, the new mineral discoveries greatly increased the country's known mineral resources. The Bureau of Mineral Resources has, since 1975, been preparing annual estimates of Australian resources of the major mineral commodities, using a classification scheme adopted in 1975 and revised in 1983. Earlier data on resources is sketchy and not strictly comparable. Nevertheless, Table 1 shows the economic demonstrated resources (which are those known in sufficient detail for mining to be carried out or planned for, and which can be worked economically) of the major commodities at the end of 1985 and 1975 compared to earlier data where that is available.

With the resurgence of growth in the 1950s the mineral industry resumed its old role of opening up the country. More than 20 new towns were built to service the new mining operations, most of them with a population of several thousand people. Most of the towns were for mines and ports for the iron ore of the Pilbara and coal of central Queensland.

TABLE 1

Australian Economic Demonstrated Resources,
Major Mineral Commodities

(Mt unless otherwise indicated)

Commodity	Pre 1965 (with date)(a)	1975	1985
Bauxite	21.1 (1954)	3 000	2 889
Black coal (recoverable)	4276 (1962)(b)	19 500	34 000
Brown coal (recoverable)	17000 (1960)	12 600	41 900
Copper	1.3 (1960)	5.9	16.1
Diamond (10 ⁶ carat)			
gem	neg	neg	187
industrial	neg	neg	229
Gold (t)	250 (e) (1960)	156	959
Iron ore	374 (1959)	17 800	16 220
Lead	4.3 (1960)	13.9	14.5
Manganese ore	<2 (1962)	490	326
Nickel	neg	1.9	1.7
Petroleum (10 ⁶ m ³)			
crude oil	neg	243	231 (f)
natural gas	neg	326 100	691 000 (f)
Silver	0.007 (1960)	0.024	0.031
Tin	0.028 (1960)(c)	0.332 (c)	0.262
Titanium (concentrate)			
ilmenite	3.5 (d) (1955)	58.4	41.4
rutile	2.5 (1955)	9.2	8.0
Uranium (recoverable)	n.a.	0.30	0.47
Zinc	4.0 (1960)	19.3	21.2
Zircon (concentrate)	2.9 (1955)	15.7	11.5

(a) Data only partly on same basis as that making up later totals.

(b) Excludes Victoria, where reserves were small. Not specified whether in situ or recoverable.

(c) Recoverable; in situ resources estimated to be about 20% higher.

(d) Not suitable for pigment production.

(f) June 1985

neg = negligible or nil.

However, companies had been seeking alternatives to the high direct and indirect costs of establishing and running towns in isolated parts of Australia, and in the 1980s a new pattern began to emerge. This is to house only a few key people permanently at the operation site; the rest of the workforce live in an existing well-established town and are transported to and from the site, where they live for a week to 10 days or so in motel type accommodation. The operators of the Cooper Basin petroleum fields in the northeast of South Australia began this practice in 1966, flying the workers 800 km between Adelaide and Moomba. Similar arrangements were instituted when large-scale operations began at the Argyle diamond mine in 1985 - most of the mine workers live in Perth, over 2000 km to the south.

Changing circumstances

While the 1960s marked the beginning of the rapid expansion of the mineral industry, it also saw the emergence of forces which drastically changed the industry's financial arrangements, and the industry's relations with government and the public.

Hitherto, construction of mines was financed largely by equity capital or from retained profits, and where possible, development was in stages, to spread the capital requirement over time. However, mines extracting low cost commodities, such as iron ore, depend on economies of scale for economic efficiency. Purchase of equipment to give the required capacity, and construction of infrastructure, such as railways, ports and towns, to support the mining operation itself, required large pre-production expenditure. The companies turned to loan raisings as a source of funds, partly because it would have been difficult at the time to obtain the large sums required by equity raisings, and partly because this course presented taxation advantages. The loan raisings were associated with features largely new to Australian industry, such as long term sales contracts and take-or-pay sales contracts as partial security for the loan, and non-recourse lending, in which the financial institution lends money on the security of the operation, and has no recourse to the parent organisation should the operation fail.

One indirect effect of the changed financing arrangements was the commitment to interest payments and loan repayments, which greatly increased the level of fixed charges and, consequently, the adverse effect of production stoppages.

Another was that, because the bankers needed to be assured that the operation could produce the total amount of ore proposed at about the estimated cost, the shape, tonnage and grade of the orebody, and its metallurgical characteristics, had to be determined with far more confidence than generally had been the practice in the past. This further increased the pre-production expenditure, but also meant that mining could proceed in an orderly way, with little chance of surprises (usually unwelcome) because of unexpected changes in the nature of the orebody.

The changed financing arrangements were accompanied by an increase in popularity of the joint venture - a company which had found a deposit would invite one or several other companies to share in the development and running of the operation. It did this partly to reduce the financial burden and risk (although the reward was reduced correspondingly) but the partners often were selected for the other advantages they could bring to the operation, such as technical or financial expertise, and access to markets.

The Australian mineral industry is almost all owned and operated by the private sector. For much of the industry's history the relationship between it and government generally had been simple: State governments granted mining leases, ensured that the mining laws were observed, and collected royalties; the Commonwealth government collected those taxes to which it was entitled.

Many of the new mines were planned as large scale operations from the very beginning. They needed a large workforce - which had to be housed and provided with community services - and transport facilities to handle millions of tonnes of product each year. Rather than provide these facilities themselves, Governments made it a condition of many new mining leases that the companies provided, or made a major financial contribution to, the infrastructure for the mining operation - not only the railways and ports, but the social infrastructure such as streets, houses, schools, hospitals and recreation facilities, on the scale required. This

requirement arose partly because governments had difficulty finding the funds required because of competing demands in a time of rapid economic expansion; but another argument was that, because the mineral deposits belonged to the State, the benefits of their exploitation should go to the public generally as well as the companies concerned. Some governments took this argument further, and made the industry a source of revenue additional to the relatively small amount of royalty payments by imposing charges for services (eg rail freights) considerably higher than the cost of providing the service.

Governments also saw the new mining operations as a trigger for industrial development, and the grant of some mining leases was conditional on the company agreeing to a timetable to establish (provided it could be justified economically) facilities to process the ore to some degree.

Because the standard mining leases allowed by mining acts were not suitable for the scope of many of the new operations, and because of the special conditions which the government wished to impose on the operation, many of the new developments each were catered for by a special act of the State Parliament, which set out the rights and obligations of the developer and the government.

In the 1950s the industry also began to be affected by increasing public concern for the quality of the environment.

With the increasing awareness that preservation of natural features such as scenery and plant and animal habitats had a value to society - although this was difficult to quantify in financial terms - governments increased the controls on discharge of potentially polluting emissions such as water containing sediment or chemicals, and noxious gases. Whereas the industry once, by and large, had priority in land use, it now had to justify its activities in competition with other potential uses of the land.

Governments also took account of the likely effect of a proposed mining or treatment process on the surroundings before deciding whether it should go ahead, and required that, where feasible, mined-out areas be rehabilitated by reshaping and revegetating the surface so that the site could be used for other purposes.

The mineral industry's former priority for land use was eroded further in the 1970s when title to extensive tracts of land in the Northern Territory and some States was granted to the land's traditional aboriginal owners. One result of this was that companies had to obtain the consent of the aboriginal owners before they could explore or mine on such land. Because of the significance of land in aboriginal society, and because of the owners' wish to minimise the effect of a different culture on their traditional way of life, this requirement commonly required prolonged negotiations and this in turn added to the costs and uncertainty of the mineral exploration process.

These new influences - the need to provide infrastructure, the need to service large loans, increased pollution controls, and the uncertainty as to when or whether a deposit, even if it was economic, could be worked - all added to the industry's costs and risks.

The industry today

In the late 1970s, the rate of growth of the mineral industry in Australia, which had been maintained for more than 15 years, began to slow. New mines had been developed around the world to meet a forecast demand for minerals which turned out to be overly optimistic. The Australian industry's costs had increased but, in general, mineral prices had not. It was largely dependent on exports and had to compete for sales with mines in other countries; some of these mines were less affected by cost increases, or were assisted in various ways by their governments.

Many new coal mines were established in Australia after the second oil shock in 1979, but world demand stagnated, leaving the industry in Australia (and the world) with substantial surplus capacity. Metal prices failed to increase in line with the world economic upturn in the early 1980s, and few new metal mines were opened - Australian production increased largely because of capacity increases at existing mines to achieve economies of scale.

Statistics show mine production and exports increasing year after year, but the return on funds employed generally was low and a number of mines closed because they had become uneconomic.

Petroleum exploration expenditure had increased rapidly after the second oil shock in 1979; several new commercial fields were discovered, especially in southwest Queensland, and, because of the greatly increased price of crude oil, decisions were made to develop some hitherto uneconomic fields. The increase in economic resources pushed back by several years the time when Australia's relatively high self-sufficiency in crude oil would begin to fall. However, the collapse of world crude oil prices in the first quarter of 1986 completely changed the fortunes of the petroleum industry. Production fell (mainly because of virtual cessation of exports), exploration was reduced sharply, and development of a number of fields was deferred.

At the exploration stage also, the industry has to meet new challenges. Not surprisingly, the mineral deposits found in the first century or so of mineral search were those well exposed at the surface; and the first petroleum accumulations found tended to be the larger, better delineated, ones. Consequently, finding further economic ore bodies and petroleum accumulations has become progressively more difficult, requiring the use of an increasingly larger and more specialised range of exploration techniques and increasingly better skills in applying suitable methods and interpreting the results. The geologist searching for metalliferous deposits now has to do what the petroleum explorationist has always done - rather than searching directly for the deposit itself, to use indirect methods by identifying geochemical or geophysical features which might represent a deposit. Indeed, this is the only possible procedure in the search for blind metalliferous deposits (those not exposed at the earth's surface, but covered completely by barren or near barren rock) to which the search increasingly is being directed. An example of such a deposit is the huge Olympic Dam orebody, which is covered by 300 metres of rock in which there is no sign of mineralisation.

However, while the constant improvement of exploration techniques has enabled discoveries to continue, it has also meant that the search has become much more expensive. Increasingly, the rewards are likely to go to those with the resources, persistence and optimism to spend large amounts of money year after year.

By the mid 1980s, one of the few bright spots in the Australian mineral industry was gold. Because its price was fixed, gold was largely ignored in the expansion of the industry after World War 2. Interest revived to some extent when the price was freed in 1968 and strengthened with increasing confidence that the price increases of the late 1970s were likely to be sustained.

Two other factors heightened the interest. One was the development of an efficient method of recovering very fine grained gold; the other was the realisation that modern methods allowed the economic mining by open cut and treatment of an entire zone of gold bearing veins (both the veins and the intervening barren rock) whereas in the past only the veins themselves would have been mined, by high cost methods.

So another gold mining boom emerged in the early 1980s. Australian gold production multiplied from 18t in 1981 to 57t in 1985. In 1984 and 1985 alone, 24 new gold mines were opened, and retreatment of old tailings began at several centres. Notably, almost all the deposits opened up were close to or at old mines - very few were completely new discoveries.

History probably will show that the 1980s was another period of change for the mining industry: a period of consolidation rather than expansion, especially in the structure of the industry, even though the volume of production continued to increase; a period of increasing diversity of export markets, with reduced dependence on a few major customers; a period of strenuous efforts to improve the efficiency of operations; and a period in which the Australian industry, despite far-reaching changes in world mineral production and consumption patterns, was able to retain its role as a major supplier to international markets, and a major source of income for the Australian economy.