Australia's Identified Mineral Resources 1993

B R S

Summary

The Australian mineral industry, a most important sector of the Australian economy, is founded on a rich and diverse resource endowment. In 1992–93 the value of mineral exports was $29 748 million, which was almost 63% of all commodity exports for that year.

Australia's gold and base metal resources in the Economic Demonstrated Resources (EDR) category increased significantly in 1993. In contrast, diamond EDR decreased substantially for both industrial and gem categories, but subeconomic resources for both categories rose sharply. Other major commodities such as bauxite, black coal, brown coal, iron ore, manganese ore, mineral sands and nickel had minor or no change in EDR.

Internationally, Australia continues to be a leading mineral resource nation. It is one of the world's top six countries for commodities as diverse as bauxite, gold, iron ore, lead, zinc, mineral sands and uranium. During the past year there were successful exploration programs at many known deposits and in greenfield regions. At a number of mines resources were increased progressively despite mining over an extended period.

Mineral exploration expenditure in Australia rose marginally in 1992–93 to $631.8 million, indicating some recovery from the downward trend of the last four years. Gold continued to be the main exploration target, attracting 50.7% of the total 1992–93 expenditure.

Introduction

The diversity and quality of Australia's mineral endowment is recognised worldwide. This wealth of resources enables Australia to maintain its position as one of the world's most important suppliers of minerals (Williams 1992). The high potential for future mineral discoveries provides incentive for further exploration. This report presents the second annual assessment of Australia's identified mineral resources by the Bureau of Resource Sciences (BRS). It continues and is consistent with the resource assessment series published annually by the former Bureau of Mineral Resources, Geology and Geophysics (BMR).

The assessment is undertaken as input into government policy decisions relating to resource and environment management for sustainable development. The report also examines Australia's position in world rankings and trends in EDR of major commodities and some minor commodities. It provides a perspective on mineral exploration in Australia by analysing trends in expenditure and exploration in this country over the past 23 years. The report summarises changes in exploration expenditure for groups of mineral commodities over the last four years.

Table 1 shows preliminary figures, published by the Australian Bureau of Agricultural and Resource Economics (ABARE), for the value of various Australian mineral exports in 1992–93. It demonstrates the relative importance of the contributions of various mineral commodities to Australia's export income.

Table 2 presents estimates of Australia's identified resources of major (and a number of minor) mineral commodities for 1993. These estimates were prepared by the Mineral Resources Branch of BRS and are based on published and unpublished data available up to early November 1993. To put resource totals in perspective, data for Australian mine production and for world resources and mine production are included. Australia's mine production data (recorded in Table 2) were provided by ABARE, and petroleum production data by the Petroleum Resources Branch of BRS. World data have been obtained or calculated from various sources, mainly US Bureau of Mines publications. Data on 1992–93 production, exports and value of exports referred to in this report are preliminary figures published by ABARE (1993).

The classification used in the Table 2 was adopted by the former BMR in 1975 (BMR 1976) and refined in 1983 (BMR 1983). It reflects both the geological certainty of occurrence of mineral resources and the economic feasibility of their extraction (see Terminology and Definitions). EDR are used instead of 'reserves' for national resource totals in Australia because the term reserves is used by various groups to describe different resource categories. The 'paramarginal' and 'submarginal' subdivisions of subeconomic resources refer to the feasibility of extraction at current prices using existing technology. Paramarginal resources border on being economically producible, whereas extraction of submarginal resources would require a substantially higher commodity price or a major cost-reducing advance in technology.

Table 3 presents uranium resources, which are classified by BRS in categories adopted by the Organisation for Economic Co-operation and Development Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA) classification (see Uranium). 'Reasonably Assured Resources' of the OECD/NEA and IAEA classification can be equated with 'demonstrated resources' of the BMR classification (above), and 'Estimated Additional Resources-Category I' with 'inferred resources'. Resources recoverable at a cost of less than US$80/kg uranium (U) used to be equated with EDR and resources recoverable at a cost of US$80–130/kg U with 'paramarginal resources'. In 1993 most uranium was sold at prices below US$80/kg and resources recoverable at a cost of less than US$80/kg U are not necessarily EDR.

Mineral Commodities

Trends in EDR for black coal, bauxite, iron ore, gold, copper, lead, zinc, nickel and mineral sands since 1975 are shown in Figure 1. The preliminary export value of mineral commodities and value added products totalled $29 748 million in 1992–93. Table 1 shows the value of the various mineral exports.

Bauxite

Australia produces about 40% of world bauxite and over 35% of world alumina, making it the largest producer of bauxite and alumina. Australia's production of bauxite, which rose by an estimated 3% in 1992–93, is forecast by ABARE to decrease only marginally in 1993–94 to 41.0 million tonnes (Mt). World bauxite reserves and resources plus alternative sources of alumina remain adequate to satisfy world demand for the foreseeable future.

Australia's bauxite EDR and the ratio of EDR to identified (demonstrated plus inferred) resources remained virtually unchanged since the 1992 assessment. Bauxite is mined from open-cut operations at Weipa (Qld), Gove (NT) and in the Darling Range (WA). Major bauxite resources in the Admiralty Gulf region of northern Western Australia are potentially mineable, but are remote from energy supplies and infrastructure. Alumina refineries are located in the vicinity of the Gove and Darling Range mines. Bauxite from Weipa is refined at Gladstone (Qld) or shipped direct to overseas customers.

Black coal

Australian production of raw black coal in 1992–93 was 222.1 Mt, an increase of 3.8 Mt over the previous year. Australia's EDR is about 8% of world economic black coal resources. In terms of resources Australia ranks fifth behind the US, the former USSR, China and South Africa. EDR increased sharply in 1986 as result of a major reassessment of resources in New South Wales by its Department of Mineral Resources. The minor fluctuations in other years resulted from additions due to exploration and losses due to production. EDR decreased slightly in 1993 for similar reasons.

About 44% of Australia's EDR of black coal are situated in the Sydney Basin, 35% in the Bowen Basin and 14% in the Galilee, Surat, Morton and Gunnedah Basins together. The proportion of open-cut coal in the Sydney and Bowen Basins is 39% and 61% respectively. Locally important but relatively small resources occur in Tasmania, South Australia and Western Australia. A consequence of the large EDR relative to annual production is that exploration expenditure is low and is unlikely to rise significantly in the short term.

Table 1: Value of mineral exports 1992–93

Commodity	Export value ($ million)	Proportion of total mineral exports (%)
Bauxite, alumina, aluminium	4141	13.9
Black coal	7523	25.0
Copper	790	2.7
Diamond	483	1.6
Gold	4302	14.5
Iron ore	2895	9.7
Manganese ore	213	0.7
Mineral sands	595	2.0
Nickel	645	2.2
Lead	407	1.3
Zinc	1020	3.4

Source: ABARE

Cobalt

Australia produces more than 8% of world cobalt output and in 1992 was the fourth largest producer after Zaire, Zambia and the former USSR. Australia's cobalt output is principally a by-product of nickel mining and processing. Most output is exported.

Cobalt products produced at the Yabulu nickel refinery (Qld) are mainly from the processing of lateritic nickel ores imported from New Caledonia and Indonesia. Queensland lateritic nickel ore is supplied to the refinery from Marlborough and from stockpiles derived from the Greenvale mine, which closed in 1993. Cobalt (in nickel cobalt sulphide) is produced at the Kwinana nickel refinery (WA) from the treatment of nickel matte derived from concentrates produced at Kambalda and Leinster. A small quantity of cobalt oxide is produced during zinc refining at Risdon (Tas.).

Australia's EDR of cobalt rank sixth after Zaire, Cuba, Zambia, New Caledonia and the former USSR, but represent only 1% of the world total. In 1990 reclassification of resources associated with nickel sulphide mineralisation reversed the decreasing trend in EDR that resulted from mining the Greenvale deposit. In 1993 EDR decreased slightly as resources at Greenvale were exhausted.

Copper

Australia has about 6% of world EDR and ranks fourth with Poland after the former USSR (11%), the US (14%) and Chile (27%). In production Australia ranks fifth with Poland. Chile, the US, Canada and the former USSR are the main producers.

Australia's resources of copper are mainly at the Olympic Dam copper–uranium–gold deposit in South Australia and the Mount Isa copper–lead–zinc deposit in Queensland. Other important copper resources are the Northparkes (NSW), Osborne (Qld) and Ernest Henry (Qld) copper–gold deposits and the Nifty (WA) copper deposit.

Identified resources decreased by 0.5% during 1993. EDR increased threefold, mainly because of a major reassessment and reclassification of some resources from the inferred category at Olympic Dam. Additional resources reported during the year at the Ernest Henry, Northparkes and Esperanza (Qld) deposits and a reclassification of resources at the Golden Grove (WA), Mammoth (Qld) and CSA (NSW) mines also contributed to the change.

Paramarginal demonstrated resources increased by 24% following the reassessment and transfer of some Olympic Dam resources from the inferred category and the addition of a new resource at Eloise North in Queensland. The reduction in inferred resources resulted largely from the Olympic Dam reassessment.

Diamond

Australia has been the world's largest producer of natural rough diamond since the mid-1980s but only a relatively small proportion of its output is of gem quality. This is reflected in Australia's sixth ranking, in terms of value of world diamond production, after the southern African producers and Russia. Australia has the world's largest resources of industrial diamond.

Most of Australia's diamond resources are in the Argyle AK1 pipe deposit in the Kimberley region of Western Australia. Small resources occur in alluvial deposits derived from the AK1 pipe, Ellendale pipes 4 and 9 (WA), and the alluvial 'deep lead' deposits at Copeton (NSW).

Prospects such as Merlin (NT), Coanjula (NT), Aries pipe (WA), Ellendale pipe 17, Copeton and Bingara (NSW) are being evaluated by bulk sampling and drilling. Results are encouraging with macro and micro diamonds being recovered at all sites. Some production of diamonds is under way from gravels and surface weathered material associated with the Aries pipe.

Exploration activity remains high and is focused on areas of known diamond occurrences such as the Kimberley, McArthur (NT) and to a lesser extent Copeton/Bingara regions. Diamond explorers continue to show interest in South Australia, particularly in the north of the State. Forty diamonds, mainly of gem quality, were recovered from shallow offshore leases in the Bonaparte Gulf (WA). The Argyle AK1 pipe, some 150 km inland, may be the source of these diamonds.

Identified resources decreased by 23% compared to the 1992 assessment. This reduction occurred equally in the gem/cheap gem and industrial diamond categories. Reduction in EDR and increase in paramarginal resources resulted from reclassification of some resources in the AK1 pipe.

Gold

Australia has about 8% of world EDR and ranks fourth after South Africa, the former USSR and the US. It is now the world's third largest producer, after South Africa and the US, and accounts for about 11% of world output.

The strong resource growth recorded in 1993 was due to the rise in the price of gold and the combined effects of successful exploration and reassessment, particularly at some mines. Exploration expenditure for gold was $320 million and accounted for half of all minerals exploration expenditure in Australia in 1992–93.

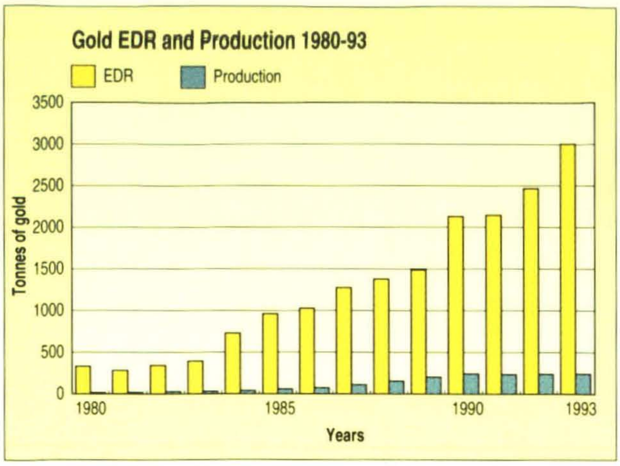
Identified resources of gold rose by 558 t (12%) in 1993 to a record 5264 t. This growth reflects the continued success of substantial gold exploration programs in extending resources in known deposits and in defining resources in new deposits. Significantly, the increase in identified resources was achieved while the industry maintained a high level of production (243.9 t in 1992–93).

Overall, demonstrated resources rose by 1037 t to 4274 t, an increase of 32%. Within this category EDR increased by 537 t to a record 3003 t, mainly as a result of increases at existing mines. This rise in EDR continues the strong growth trend established in the 1980s.

Subeconomic resources rose to 1271 t, an increase of 500 t. This resulted, in part, from the reclassification of resources from the inferred to the demonstrated category. An important outcome of continuing exploration was a reduction, by one-third, in the tonnage of inferred resources. Further exploration and assessment by companies provided additional data, which resulted in the transfer of some of the inferred tonnages into the demonstrated category.

Western Australia remained the premier gold State with 66% of EDR. It accounted for about 73% of Australia's gold production in 1992–93. Resources occur and are mined in all States and Territories except the Australian Capital Territory.

Gold exploration in the 1980s and 1990s, together with the introduction of carbon-based processing technology, resulted in a substantial increase in EDR (Fig. 2). These



resources supported the significant increase in production (from 17 to 243.9 tonnes per year) during that period. Production rose from 5% of EDR in 1980 to 8% in 1993. If production is to be maintained at this rate further increases in resources will be necessary and will require a vigorous and successful exploration program. The sustained rise in the price of gold that occurred in 1993 should help support continued strong exploration during 1994.

Iron ore

Australia's iron ore resources continue to provide the foundation for one of its major export industries. Australia currently produces about 12% of world iron ore output and in 1991 overtook Brazil to regain its ranking as the world's largest exporter. As a world producer Australia ranks fourth after the former USSR, China and Brazil. Australia's EDR of iron ore rank second after the former USSR.

Australia's identified iron ore resources are very large, with about 90% occurring in the Pilbara, mostly in the Hamersley Basin, one of the world's major iron ore provinces.

EDR represent slightly more than 35% of total identified resources. The reduction in EDR between 1975 and 1976 resulted from the reclassification of some phosphorus-bearing resources. Since then EDR have had a gradual upward trend. The increase between 1990 and 1991 reflects the results of additional exploration, which resulted in the upgrading of inferred resources to EDR. EDR increased marginally in 1992 and 1993 with minor reclassification of some resources.

In response to a substantial rise in export demand for Australian iron ores since the mid-1980s (particularly from China, South Korea and Taiwan), more than a dozen new iron ore projects have been proposed or commissioned, mainly in the Pilbara region of Western Australia. Expansions at Deepdale and Channar, and new mines established at Yandi (Marillana Creek) and being constructed at Marandoo, will play a major role in meeting export demand in the next decade.

Despite three decades of falling prices in real terms, Pilbara iron ore remains competitive on export markets, and the industry is a leader in adopting advanced technology and mining methods. Recent large-scale investment in new mining capacity and ore handling equipment, optimisation of deposit development, and the adoption of other cost efficient mining strategies will lead to further increases in productivity and efficiency.

Given its raw materials base and the needs of the expanding steel industries in Asia, Australia seems likely to continue to be a predominant supplier of relatively unprocessed iron ore. However, value adding is being pursued and the industry is in the forefront of investigations into new iron and steel making technology that is likely to become important during the early decades of the 21st century.

Manganese

Australia's resources of manganese ore support a valuable export industry and significant domestic ferromanganese, silicomanganese and manganese dioxide processing. Australia produced more than 6% of world manganese ore output in 1992 and was the third largest exporter after Gabon and South Africa. The principal mines and resources are located at the world-class Groote Eylandt deposit (NT) and Woodie Woodie in the Pilbara (WA). Higher prices in the late 1980s enabled production of manganese ore, formerly classified as paramarginal, to resume in 1990 from small deposits at Woodie Woodie.

Australia has just over 12% of world EDR and ranks third after South Africa (46%) and the former USSR (38%). The decline in Australia's EDR since 1975 mainly reflects the reclassification of data in the early 1980s following the availability of more detailed information, a re-evaluation of resources after more intensive exploration in the mid-1980s, and depletion as a result of mining.

Mineral sands

Australia has 31% of world economic resources of ilmenite, 17% of rutile and 29% of zircon. With the exception of large inland undeveloped deposits in western Victoria and south-west New South Wales, most of Australia's resources occur along the eastern and western coastal regions.

Identified resources increased by 10% for ilmenite, 4% for rutile and 5% for zircon in 1993, with EDR up by 3–4% for each commodity. EDR not available for mining because they occur in national parks and other reserved areas total 10 Mt of ilmenite, 3.2 Mt of rutile and 3.3 Mt of zircon. This equates to 9%, 23% and 16% of national EDR of ilmenite, rutile and zircon respectively. Over 70% of EDR not available to mining are in Queensland. Unavailable inferred resources are about a quarter of EDR and 80% of the ilmenite portion is in Western Australia.

Offshore exploration along the central and northern coast of New South Wales in the period from 1967 to 1972 established low grade inferred resources containing 0.7 Mt ilmenite and 2.2 Mt combined rutile and zircon. These resources are currently considered uneconomic.

Nickel

The nickel industry supports substantial domestic value adding as most nickel exported is in smelted and refined forms. The industry also produces significant copper, cobalt and platinum group metal as by-products.

Australia produces about 6% of the world's total annual nickel mine output and in 1992 its output ranked fifth behind Russia, Canada, New Caledonia and Indonesia. The main Australian mines are at Kambalda, Leinster and Forrestania in Western Australia and at Marlborough in Queensland. Smelting operations are located at Kalgoorlie and refineries at Kwinana (WA) and Yabulu (Qld). Australia's EDR rank sixth in the world after Cuba, Russia, Canada, New Caledonia and Indonesia. Almost all EDR (98%) are in sulphide deposits in Western Australia.

Changes in nickel EDR after 1975 partly reflect the impact of nickel price fluctuations on the economics of mining. Several mine closures occurred in the late 1970s and again in the mid-1980s as a result of depressed prices. The substantial increase in EDR in 1990 and 1991 resulted from reclassification of resources at a reopened mine and at projects where open-cut mining was assessed to be economically viable. A 6% increase in 1993 resulted mainly from an increase in resources at Yakabindie, Leinster and Kambalda (WA), and reclassification of resources at Forrestania (WA) and Marlborough (Qld), where mining commenced at the end of 1992 and in 1993 respectively.

The Australian nickel industry is currently undergoing major expansion and revitalisation in expectation of forecast market growth. These programs are expected to result in an expansion of Australia's world market share and further improvement in Australia's competitive position, which is based mainly on the mining of relatively shallow sulphide deposits. Smelting and refining capacity is being increased, work concerned with doubling mine production capacity at Leinster is nearing completion, and development of a major $450 million open-cut mining project based on disseminated nickel sulphides at Mount Keith is proceeding. A number of additional nickel mining projects are also proposed or under investigation in Western Australia.

Platinum group metals

There is minor production of platinum group metals (PGM: platinum, palladium, osmium, iridium, rhodium and ruthenium) in Western Australia as a by-product of nickel mining at Kambalda and nearby Carnilya Hill in the Kalgoorlie region. PGM (mainly platinum and palladium) are recovered at Port Kembla from the processing of by-product copper sulphide residue produced at the Kwinana nickel refinery. PGM are also present in nickel matte produced at Kalgoorlie for export.

Australian mine production of PGM represents about 2% of world output. Movements in EDR, which are mostly contained in nickel sulphide deposits at Kambalda and Carnilya Hill, largely reflect changes in nickel resources at these locations. EDR decreased in recent years but increased slightly in 1993. EDR comprise platinum (26%), palladium (47%) and other PGM (27%).

Exploration resulted in the discovery of substantial resources of PGM in Australia in recent years but these resources are not commercially viable. Most resources are in Western Australia. Substantial inferred resources occur at Munni Munni in the Pilbara. Resources in a similar setting to those at Munni Munni occur at nearby Mount Sholl and at Panton near Halls Creek in the Kimberley region. In 1993 relatively large resources were discovered at Range Well and Weld Range, in the Murchison region, 370 km north-east of Geraldton.

Zinc and lead

On the basis of the 1993 assessment Australia has the world's largest EDR of both zinc and lead. In terms of production, Australia is the world's largest producer of lead and the second largest producer of zinc after Canada.

EDR for both zinc and lead rose substantially in 1993 to 37.6 Mt and 19 Mt respectively. These increases mainly reflect a reclassification of paramarginal resources into EDR at the McArthur River deposit (NT) and Hilton mine (Qld). Resources at mines elsewhere decreased due to production or remained virtually unchanged.

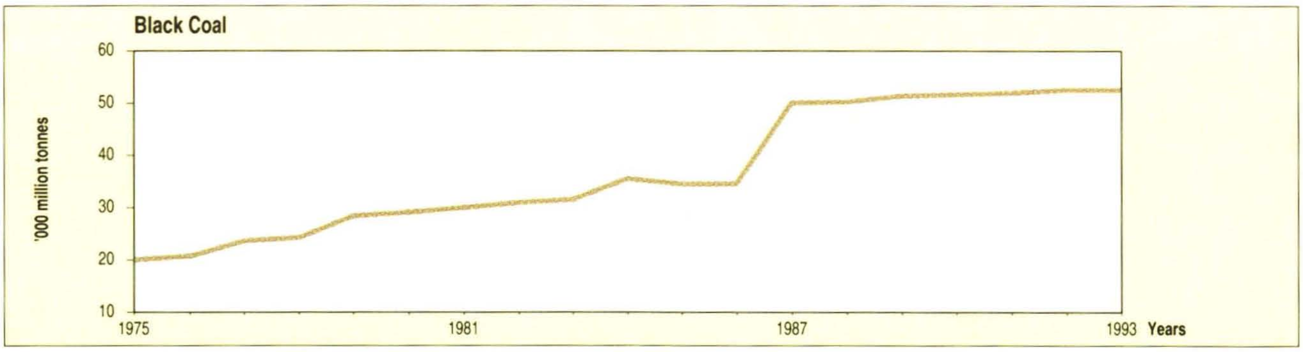
Discoveries in north-west Queensland such as those at Century and Cannington confirm that the region is one of the world's major base metal provinces. Exploration is continuing at a high level in the search for additional deposits and in the delineation of those already discovered. The province is expected to continue to attract a substantial portion of base metal exploration expenditure. Research into the treatment of the high silica ore at Century is ongoing.

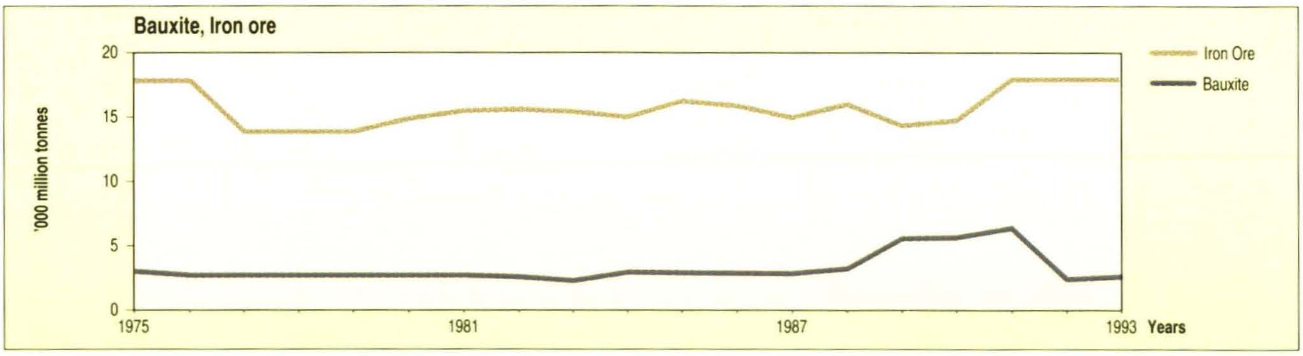
Magnesite

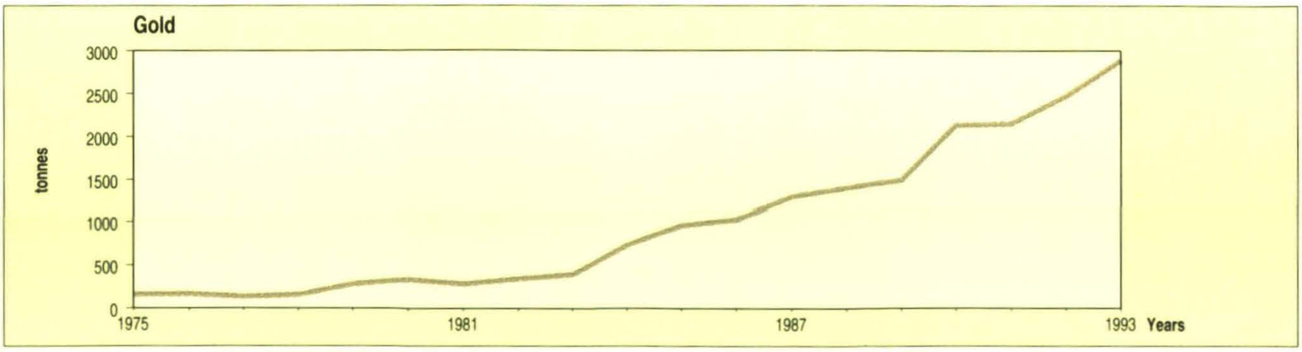
Magnesite from the world-class Kunwarara magnesite deposit (Qld) is used to produce deadburned and electrofused magnesia for refractory use (e.g. in brick linings in steel-making furnaces). Research and development is in progress to produce calcined magnesia for environmental protection in industrial processes and effluent treatment, magnesium metal, magnesium hydroxide fire retardants, and magnesia-based cements.

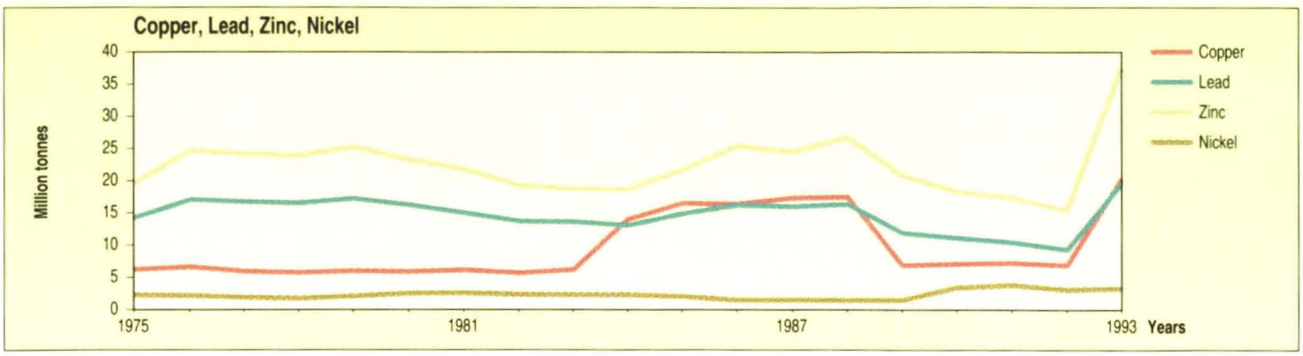
Industrial minerals

From data published by the States/NT mines departments, the Mineral Resources Branch estimates that the value of production of industrial minerals in Australia is about $1700 million annually. This includes commodities such as clays, construction materials, dimension stone, peat, salt and silica. Broken rock aggregates (used mainly in road construction), dimension stone and salt account for about two-thirds of the total value.


Black Coal
'000 million tonnes
60
50
40
30
20
10
1975
1981
1987
1993
Years


Bauxite, Iron ore
'000 million tonnes
20
15
10
5
0
1975
1981
1987
1993
Years
Iron Ore
Bauxite


Gold
tonnes
3000
2500
2000
1500
1000
500
0
1975
1981
1987
1993
Years


Copper, Lead, Zinc, Nickel
Million tonnes
40
35
30
25
20
15
10
5
0
1975
1981
1987
1993
Years
Copper
Lead
Zinc
Nickel

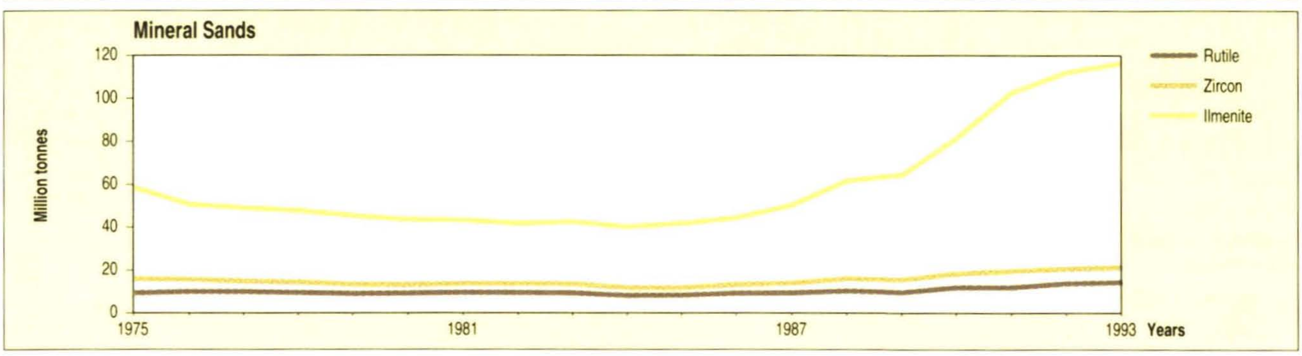

Mineral Sands
Million tonnes
120
100
80
60
40
20
0
1975
1981
1987
1993
Years
Rutile
Zircon
Ilmenite

Table 2. Identified resources of major minerals and fuels 1993

COMMODITY	UNITS	AUSTRALIA							WORLD 1992	
		Demonstrated			Inferred			Mine production 1992	Economic demonstrated resources	Mine production
		Eco-nomic	Subeconomic		Eco-nomic	Sub-economic	Undifferent-iated			
			Para-marginal	Sub-marginal						
Antimony	kb Sb	116.5	87.6	-	-	-	13.7	1.9	4200	61
Asbestos									110	3.4
Chrysotile ore	Mt	-	46	-	-	-	75	-		
Crocidolite fibre	Mt	-	0.4	-	-	-	2.1	-		
Bauxite	Mt	2582	-	5303	-	-	2134	39.7	23000	105
Black coal										
In situ	Gt	69	1	6	-	-	very large			
Recoverable	Gt	52	1	4	-	-		0.2 (2)	650	3.2 (3)
Brown coal										
In situ	Gt	46	1	2	-	-	184			
Recoverable	Gt	42	1	2	-	-	165	0.050	270	1.3
Cadmium	kt Cd	84.7	40.1	1.7	-	-	8.2	2.0	540	20
Chromite	Mt	-	2.37	0.52	-	20	-	-	1400	12.8
Cobalt	kt Co	52	47	242	-	98	-	0.95	4000	24.8
Copper	Mt Cu	20.2	17.2	0.8	5.5	2.6	-	0.4	323	8.9 (1)
Diamonds										
Gem & near gem	10^6 c	147	150	0.1	-	-	8.6	} 40.2	300	42.9
Industrial	10^6 c	189	186	0.5	-	-	25.3		980	42.9
Fluorine	Mt F	-	24.1	5.8	-	-	0.7	-	108	1.8
Gold	t Au	3003	1206	65	-	-	990	242.5	44000	2170
Iron ore	Gt	17.9	12.9	0.4	7.2	10.6	-	0.112	150	0.845
Lead	Mt Pb	19.4	8.9	5.9	-	-	16.8	0.6	63	3.2 (1)
Lithium	kt Li	160	-	3	-	-	7	2.2	2200	6
Magnesite	Mt-$MgCO_3$	218.7	188	285.2	-	-	8.8	0.27	2500	3.1
Manganese ore	Mt	107	26	167	69	94	-	1.205	800	18.8
Mineral sands										
Ilmenite	Mt	116.1	67.2	0.1	-	-	93.6	1.8	380	6.1 (5)
Rutile	Mt	14.0	33.4	0.2	-	-	26.5	0.18	85	0.4 (5)
Zircon	Mt	20.9	24.2	0.2	-	-	21.3	0.36	73	1.1
Molybdenum	kt Mo	-	-	3	-	222	-		5500	108
Nickel	Mt Ni	2.9	1.6	3.8	-	3	-	0.055	47	0.916
Niobium	kt Nb	3.4	68	-	-	-	1994	-	3500	14
Petroleum (recoverable) (4)										
Crude oil	GL	258	-	40	-	-	-	27.4	158517	3484
Natural (sales) gas	10^9m^3	950	-	1088	-	-	-	23.7 (6)	138338	2153
Condensate	GL	124	-	56	-	-	-	3.7	-	-
LPG naturally occur.	GL	131	-	83	-	-	-	3.7	-	-
Phosphate rock	Mt	-	2095	-	-	-	1947	0.002	12000	141
PGM (Pt, Pd, Os, Ir, Ru, Rh)	t metal	17.7	20.7	16.7	3.5	109.5	-	0.7	56000	294
Rare earths										
REO & Y_2O_3	Mt	1.0	3.5	10.6	-	-	4.0	-	100	0.05
Shale oil	GL	-	-	4564	-	40468	-	nil	na	na
Silver	kt Ag	33.6	17.0	3.9	-	-	31.9	1.22	280	13.7
Tantalum	kt Ta	6.3	6.0	0.09	-	-	65	0.27	22	0.41
Tin	kt Sn	123.3	139.6	77.2	-	414	5.3	6.6	8000	200
Tungsten	kt W	1.1	95.1	106.2	-	81.8	-	0.16	2300	39.8
Uranium (see Table 3)	t U							2334		36581
Vanadium	kt V	19	1739	8425	-	2282	-	-	10000	32.1
Zinc	Mt Zn	37.6	30.6	3.9	-	-	13.5	1.02	140	7.4 (1)

Abbreviations: t = tonne; c = carat; m^3 = cubic metre; L = litre; kt = 10^3t; Mt = 10^6t; Gt = 10^9t; GL = 10^9L; e = estimate.

(1) Western world only.
(2) Raw coal.
(3) Saleable coal.
(4) Source: Petroleum Resources Branch, BRS (as at 1 Jan. '92)
(Production as at 31 Dec. '92).
(5) Excludes USA.
(6) Includes ethane.

Table 2: Identified resources of major minerals and fuels 1993

		AUSTRALIA							WORLD 1992	
		Demonstrated			Inferred					
			Subeconomic							
		Economic	Para-Marginal	Sub-Marginal	Economic	Subeconomic	Undifferent-iated	Mine production 1992	Economic demonstrated resources	Mine (e) production
Antimony	(kt Sb)	116.5	87.6	-	-	-	13.7	1.9	4200	61
Asbestos									110	3.4
Chrysotile ore	(Mt)	-	46	-	-	-	75	-		
Crocidolite fibre	(Mt)	-	0.4	-	-	-	2.1	-		
Bauxite	(Mt)	2582	-	5303	-	-	2134	39.7	23000	105
Black coal	(Gt)									
in situ		69	1	6	-	-	very large			
recoverable		52	1	4	-	-		0.20 (2)	650	3.2 (3)
Brown coal	(Gt)									
in situ		46	1	2	-	-	184			
recoverable		41	1	2	-	-	165	0.050	270	1.3
Cadmium	(kt Cd)	84.7	40.1	1.7	-	-	8.2	2.0	540	20
Chromite	(Mt)	-	2.37	0.52	-	20	-	-	1400	12.8
Cobalt	(kt Co)	52	47	242	-	98	-	0.95	4000	24.8
Copper	(Mt Cu)	20.2	17.2	0.8	5.5	2.6	-	0.4	323	8.9 (1)
Diamonds	(10^6c)									
gem & cheap gem		147	150	0.1	-	-	8.6	} 40.2	300	42.9
industrial		189	186	0.5	-	-	25.3		980	42.9
Fluorine	(Mt F)	-	24.1	5.8	-	-	0.7	-	108	1.8
Gold	(t Au)	3003	1206	65	-	-	990	242.5	44000	2170
Iron ore	(Gt)	17.9	12.9	0.4	7.2	10.6	-	0.112	150	0.845
Lead	(Mt Pb)	19.4	8.9	5.9	-	-	16.8	0.6	63	3.2 (1)
Lithium	(kt Li)	160	-	3	-	-	7	2.2	2200	6
Magnesite	(Mt $MgCO_3$)	218.7	188	285.2	-	-	8.8	0.27	2500	3.1
Manganese ore	(Mt)	107	26	167	69	94	-	1.205	800	18.8
Mineral sands										
Ilmenite	(Mt)	116.1	67.2	0.1	-	-	93.6	1.8	380	6.1 (5)
Rutile	(Mt)	14.0	33.4	0.2	-	-	26.5	0.18	85	0.4 (5)
Zircon	(Mt)	20.9	24.2	0.2	-	-	21.3	0.36	73	1.1
Molybdenum	(kt Mo)	-	-	3	-	222	-		5500	108
Nickel	(Mt Ni)	2.9	1.6	3.8	-	3	-	0.055	47	0.916
Niobium	(kt Nb)	3.4	68	-	-	-	1994	-	3500	14
Petroleum (recoverable)(4)										
Crude oil	(GL)	258	-	40	-	-	-	27.4	158517	3484
Natural (sales) gas	(10^9m^3)	950	-	1088	-	-	-	23.7 (6)	138338	2153
Condensate	(GL)	124	-	56	-	-	-	3.7	-	-
LPG naturally occur.	(GL)	131	-	83	-	-	-	3.7	-	-
Phosphate rock	(Mt)	-	2095	-	-	-	1947	0.002	12000	141
PGM (Pt,Pd,Os,Ir,Ru, Rh)	(t metal)	17.7	20.7	16.7	3.5	109.5	-	0.7	56000	294
Rare earths										
REO and Y_2O_3	(Mt)	1.0	3.5	10.6	-	-	4.0	-	100	0.05
Shale oil	(GL)	-	-	4564	-	40468	-	nil	na	na
Silver	(kt Ag)	33.6	17.0	3.9	-	-	31.9	1.22	280	13.7
Tantalum	(kt Ta)	6.3	6.0	0.09	-	-	65	0.27	22	0.41
Tin	(kt Sn)	123.3	139.6	77.2	-	414	5.3	6.6	8000	200
Tungsten	(kt W)	1.1	95.1	106.2	-	81.8	-	0.16	2300	39.8
Uranium (see Table 3)	(t U)							2334		36581
Vanadium	(kt V)	19	1739	8425	-	2282	-	-	10000	32.1
Zinc	(Mt Zn)	37.6	30.6	3.9	-	-	13.5	1.02	140	7.4 (1)

Abbreviations: t = tonne; c = carat; m^3 = cubic metre; L = litre; kt = 10^3t; Mt = 10^6t; Gt = 10^9t; GL = 10^9L; na = not available; e = estimate; LPG = Liquid Petroleum Gas; PGM = Platinum Group Metals; REO = Rare Earth Oxides.

(1) Western world only.
(2) Raw coal.
(3) Saleable coal.
(4) Source: Petroleum Resources Branch, BRS (as at 1 January 1992); (Production as at 31 December 1992)
(5) Excludes US.
(6) Includes ethane.

Uranium

Australia is a major producer of uranium. In 1992 it ranked fourth in the world after Canada, the former USSR and Niger. Total production for 1992 from the Ranger (NT) and Olympic Dam (SA) mines was 2334 t U. Australia exports uranium to countries with which it has bilateral safeguards agreements. In 1992–93 the value of the 1941 t U in concentrates exported was $123 million.

Table 3 presents estimates of Australia's recoverable uranium resources, together with the latest available figures for other countries. The resources are shown in categories as defined by the OECD/NEA and IAEA. The Australian estimates have been calculated by the Mineral Resources Branch using basic exploration data provided by companies. The revision of estimates for 1993 takes into account production and reassessments in the light of additional exploration, cost increases, and changes in the exchange rate of the Australian dollar.

Australia's Reasonably Assured Resources (RAR) recoverable at less than US$80/kg U are 39% of the total resources in the low cost RAR category (derived from estimates published by OECD/NEA and IAEA and adjusted as shown in Table 3). Australia's RAR in this category increased by 169 000 t during the past year.

Australia's Estimated Additional Resources-Category I (EAR-I) recoverable at less than US$80/kg U are 26% of the total resources in the low cost EAR-I category (derived from estimates published by OECD/NEA and IAEA and adjusted as shown in Table 3). Australia's EAR-I in this category decreased by 123 000 t during the past year.

Australia's RAR in the US$80–130/kg U cost category increased by 21 000 t, and EAR-I in this cost category decreased by 82 000 t during the past year.

In addition to the RAR and EAR-I categories of resources shown in Table 3, BRS estimates that there is a 75% probability that Australia has undiscovered potential resources (Undiscovered Resources) amounting to more than 2 600 000 t U and a 50% probability that the Undiscovered Resources may exceed 3 900 000 t U.

Table 3: Estimated recoverable resources of uranium 1993 [1] (tonnes U)

	Cost Range to US$80/kg U [2] (US$30/lb U_3O_8)		Cost Range US$80–130/kg U [2] (US$30–50/lb U_3O_8)	
COUNTRY	Reasonably Assured Resources [3]	Estimated Additional Resources - Category I [4]	Reasonably Assured Resources [3]	Estimated Additional Resources - Category I [4]
Algeria	26 000	-	-	-
Argentina	4 600	2 300	2 700	300
Australia [5]	631 000	149 000	76 000	40 000
Brazil	162 000	94 000	-	-
Canada	276 930	31 000	118 760	43 000
France	19 850	3 550	13 800	3 180
Gabon	9 780	1 300	4 650	8 300
Korea, Republic of	23 800	-	10 200	-
Namibia	80 640	30 000	16 000	23 000
Niger	161 040	295 770	6 650	10 000
South Africa	144 400	34 720	96 440	19 700
Spain	18 000	4 200	23 000	-
Ukraine	44 000	18 200	38 400	30 100
US [6]	114 000	n.a.	255 000	n.a.
Other countries [7]	44 260	20 240	81 075	69 530
Total (adjusted) [8]	1 629 000	571 000	681 000	202 000

[1] Data for countries other than Australia are from the most recent OECD/NEA and IAEA publications available at 31 December 1993.

[2] The OECD/NEA and IAEA quote uranium production costs in US$/kg U. These cost categories should not be confused with market prices. Previous development costs or profits are not included. (US$80/kg U = US$30/lb U_3O_8 approximately).

[3] RAR refer to uranium that occurs in known mineral deposits of such size, grade and configuration that it could be recovered within the given production cost ranges, with currently proven mining and processing technology. Estimates of tonnage and grade are based on specific sample data, measurements of the deposits and on knowledge of deposit characteristics. RAR have a high assurance of existence.

[4] EAR-I refer to uranium in addition to RAR that is expected to occur, mostly on the basis of direct geological evidence, in extensions of well explored deposits and in deposits in which geological continuity has been established but where specific data and measurements of the deposits and knowledge of the deposits' characteristics are considered to be inadequate to classify the resources as RAR. Such deposits can be delineated and the uranium subsequently recovered, all within the given cost ranges. Estimates of tonnage and grade are based on such sampling as is available and on knowledge of the deposit characteristics as determined in the best known parts of the deposit or in similar deposits. Less reliance can be placed on the estimates in this category than on those for RAR.

[5] Data for Australia compiled by BRS as at December 1993.

[6] The United States EAR are not reported separately for EAR-I and EAR-II. (n.a. = not available).

[7] Austria, Central African Republic, Czech Republic, Denmark, Finland, Germany, Greece, Hungary, Indonesia, Italy, Japan, Mexico, Peru, Portugal, Slovenia, Somalia, Sweden, Thailand, Turkey, Vietnam, Zaire, Zimbabwe.

[8] Totals have been adjusted by OECD/NEA and IAEA to account for milling and/or mining losses not incorporated in the estimates for Algeria, Brazil, Republic of Korea, Ukraine and certain countries grouped under 'other countries'. Because of these adjustments these totals do not represent the sum of the country assessments detailed above. Although the Russian Federation, Kazakhstan, China and India have reported significant uranium resources, these have not been included in the above table because the estimates are either not consistent with standard OECD/NEA and IAEA resource definitions or categories, or cost categories were not assigned to the estimates.

Exploration

The Australian mineral industry started when the first settlers dug clay for brickmaking and Hawkesbury Sandstone was quarried and shaped for early buildings at Sydney Cove. Coal found near the mouth of the Hunter River in 1791 was Australia's first commercial mineral discovery. Rich copper deposits discovered in the 1840s and the 1860s in South Australia were the first base metal deposits to be worked and their output dominated world production of copper in the 1870s.

The discovery and development of rich alluvial gold deposits in New South Wales and Victoria during the 1850s and 1860s heralded the prospecting phase of mineral discovery, which lasted to about the mid-1930s. From 1851 to about 1875 numerous gold deposits were discovered in Victoria, New South Wales and Queensland and the discoveries of gold migrated westwards across the top end of Australia and then south to the rich fields at Coolgardie (1892) and Kalgoorlie (1893) in Western Australia.

The major copper-gold deposits at Mount Morgan (Qld) and Mount Lyell (Tas) were discovered in the early 1880s. One of the world's richest and largest lead–zinc deposits was found at Broken Hill (NSW) in 1883. In the late nineteenth century the development of these mineral deposits impacted dramatically on the social and economic infrastructure of Australia.

Only a few mineral discoveries were made between the turn of the century and 1950, principally because of the collapse in demand for metals and subsequent low prices following World War I, during the Depression of the 1930s, and following World War II in the 1940s. Significant discoveries during this period included King Island (1904), Mount Isa (1923) and Tennant Creek (1933).

Geological exploration, as distinct from prospecting, commenced in the 1930s. The systematic study of the geological and tectonic framework of Australia began in 1946 with the establishment of the BMR. This framework was the basis for many exploration strategies that resulted in the discovery of a wide range of minerals deposits, including some that had not been seriously explored for in Australia before that time. From 1951 to 1963 more than 40 deposits were discovered, including bauxite, manganese, mineral sands, uranium and base metals.

Annual growth rates of about 4–5% in OECD economies between 1960 and 1973 led to sustained demand for many minerals. Higher commodity prices boosted exploration, which led to discovery of the coal deposits of the Bowen Basin (Qld), the iron ore deposits of the Pilbara (WA), manganese at Groote Eylandt (NT), more than 50 base metal deposits (including the nickel deposits of the Yilgarn, WA) and several uranium deposits.

Although attention focused on nickel in the late 1960s and early 1970s and on gold in the 1980s, important deposits of base metals, iron ore, mineral sands and diamond were also discovered. The rising price of gold in the mid to late 1970s led to increased exploration activity that resulted in 41 significant gold discoveries in the period 1981–91. Base metals exploration also flourished in the same period and a number of new discoveries were reported. BMR (1992) presents an indication of the scope and type of discoveries made over the two decades.

Table 4: Selected mineral discoveries 1990–93

Commodity	State	Project /deposit
Gold	WA	Bronzewing
Gold	WA	Kanowna Belle
Gold	WA	Keringal
Gold	NT	Callie
Gold	NT	Villa
Gold	NSW	Lake Cowal
Copper, gold	NSW	Endeavour 48
Copper, gold	WA	Maroochydore
Copper, gold	Qld	Osborne
Copper, gold	Qld	Ernest Henry
Zinc-lead	Qld	Cannington
Zinc-lead	Qld	Century
Copper, lead, zinc, gold	NSW	Lewis Ponds
Mineral sands	NSW	Massidon

Table 4 lists significant discoveries made between 1990 and 1993. The list is not exhaustive and does not attempt to include many of the smaller discoveries, especially for gold. It focuses on reports of new resources but includes some reserve reassessments and drilling results considered to be of potential significance. Selection was based on public information about tonnage and grade, and the results of recent exploration programs.

The resurgence of gold mining in Western Australia in the 1980s resulted, to a large extent, from successful exploration programs aimed specifically at finding shallow, oxidised gold resources that were readily extractable by open-cut mining and easy to process. In some instances a later phase of exploration, assisted by relevant data from earlier exploration and subsequent mining, has outlined primary or less altered extensions of these resources that are amenable to underground mining.

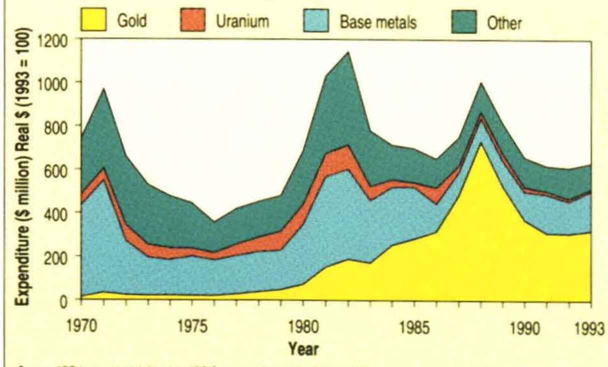
Exploration expenditure

Figure 3 shows trends in mineral exploration expenditure for commodity groups monitored by the Australian Bureau of Statistics (ABS). The differentiation of commodity groups before 1980 is based largely on a breakdown of the ABS totals by BRS. Annual expenditure on exploration increased from less than $100 million in 1968–69 to close to $800 million in 1988–89. However, the increase was relatively modest in real terms, with peaks around 1970, 1981 and 1988 that coincide with periods of high activity on national stock exchanges. Cook (1990) observed that as a proportion of mine production value, annual expenditure on exploration fell from 9% around 1970 to 3% in the late 1980s.

An obvious trend in mineral exploration expenditure is the dominance of gold exploration since the mid to late 1980s. ABS figures show that in 1992–93, gold continued to be the major single-commodity category of expenditure, accounting for 50.7% of total expenditure of $631.8 million. Base metals increased to 29.0% of total expenditure as compared to 24.0% in 1991–92 (Fig. 3). The downward trend in total mineral exploration expenditure over the last four years recovered slightly in 1992–93.

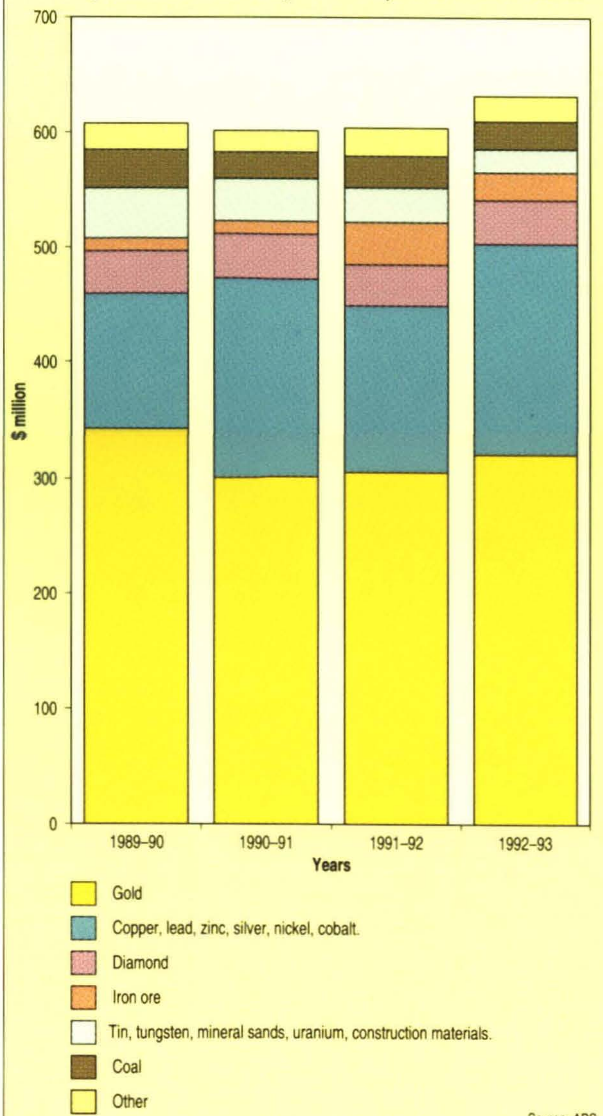
Data acquired by the Australian Mining Industry Council's Exploration Group, through a survey of major Australian exploration companies, indicate that explorers allocated about $120 million, or 26%, of their total exploration expenditure to overseas projects in 1990–91.

Fig 3a Annual mineral exploration expenditure (all minerals including coal)



Source: ABS (current and deflated by ABS Consumer Price Index 1993 = 100)

Fig 3b Annual mineral exploration expenditure since 1989-90



Source: ABS

International identified mineral resources studies

Australia, through BRS, participates in the International Strategic Minerals Inventory (ISMI). ISMI is a cooperative program between mineral resource agencies of the governments of Australia, Canada, Germany, South Africa, the UK and the US. The objective of ISMI is to report, in a publicly available form, non-proprietary data and information on the characteristics of major deposits of strategic mineral commodities as an input into policy considerations in regard to short, medium and long-term world supply.

Reports on the world's identified mineral resources published to date are:

Manganese (1984)
Chromium (1984)
Phosphate (1984)
Nickel (1985)
Platinum Group Metals (1986)
Cobalt (1987)
Titanium (1988)
Graphite (1988)
Lithium (1990)
Tin (1990)
Vanadium (1992)
Zirconium (1992)
Niobium (Columbium) and Tantalum (1993)

A Regional Assessment of Selected Mineral Commodities in Subequatorial Africa

Reports in press are:
Rare Earths
Tungsten
Eastern European Regional Resources Study.

ISMI is currently undertaking a study of lead times in the mining industry. Lead time is generally understood to be the time that elapses between discovery of a deposit and commencement of production and in the ISMI study this is defined as lead time I. Lead time II is defined as the sum of the periods during which the deposit was under active exploration, feasibility assessment, environmental or other studies, and construction. In some instances a deposit is discovered and then for some reason (e.g. market conditions) a decision is made not to proceed. Lead time III is defined as the time that elapses between the start of exploration or work phase (following the last dormant phase) and the commencement of production. When there is no inactive phase and a deposit proceeds from discovery to production, lead time III is the same as lead time I.

From preliminary results of the lead time study, based on data from deposits in Australia, Canada, the US and South America, Wellmer (1992) concluded, inter alia, there is no evidence that lead time III has increased in the past 15 years and that the lead time for gold deposits is shorter than for other mineral deposits. Analysis of data collected to date establishes that the lead time in industrialised countries such as Australia, Canada and the US is less than in developing countries in Latin America (F.W. Wellmer, pers. comm., September 1993). The lead time report is scheduled to be published as an ISMI report in mid-1995.

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TERMINOLOGY AND DEFINITIONS

RESOURCE: A concentration of naturally-occurring solid, liquid, or gaseous materials in or on the earth's crust and in such form that its economic extraction is currently or potentially (within a 20–25 year time frame) feasible.

CATEGORIES BASED ON DEGREE OF ASSURANCE OF OCCURRENCE

IDENTIFIED RESOURCES: Specific bodies of mineral-bearing material whose location, quantity, and quality are known from specific measurements or estimated from geological evidence. Identified resources include economic and subeconomic components. To reflect degrees of geological assurance, identified resources can be subdivided into the following categories:

DEMONSTRATED: A collective term for the sum of measured and indicated resources:

MEASURED: Resources for which tonnage is computed from dimensions revealed in outcrops, trenches, workings, and drillholes, and for which the grade is computed from the results of detailed sampling. The sites for inspection, sampling, and measurement are spaced so closely, and the geological character is so well defined, that size, shape, and mineral content are well established.

INDICATED: Resources for which tonnage and grade are computed from information similar to that used for measured resources, but the sites for inspection, sampling and measurement are farther apart or are otherwise less adequately spaced. The degree of assurance, although lower than for resources in the measured category, is high enough to assume continuity between points of observation.

INFERRED: Resources for which quantitative estimates are based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on an assumed continuity or repetition, of which there is geological evidence. This evidence may include comparison with deposits of similar type. Bodies that are completely concealed may be included if there is specific geological evidence of their presence. Estimates of inferred resources should be stated separately and not combined in a single total with measured or indicated resources.

CATEGORIES BASED ON ECONOMIC CONSIDERATIONS

ECONOMIC: Resources for which, at the time of determination, profitable extraction or production under defined investment assumptions has been established, analytically demonstrated or assumed with reasonable certainty.

SUBECONOMIC: Resources that do not meet the criteria of economic. Subeconomic resources include paramarginal and submarginal categories:

PARAMARGINAL: Subeconomic resources that, at the time of determination, almost satisfy the criteria for economic. The main characteristics of this category are economic uncertainty and/or failure (albeit just) to meet the criteria that define economic. Included are resources that would be producible given postulated changes in economic or technological factors.

SUBMARGINAL: Subeconomic resources that would require a substantially higher commodity price or some major cost-reducing advance in technology to render them economic.

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Roger Pratt	272 5173	*Iron ore, manganese, nickel, platinum group, vanadium, chromium, cobalt, tungsten, molybdenum*
Lloyd David	272 4127	*Titanium, zirconium, rare earths, gem and semi-precious stones, clays, magnesite, talc, dolomite, peat, limestone, gypsum, silica, fertiliser and chemical industry minerals (e.g. phosphate, potash, sodium, sulphur, fluorine, boron), specialty minerals (e.g. barite, diatomite, felspar, graphite, mica, perlite)*
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