Australia's IDENTIFIED MINERAL Resources

1995

BRS

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The Bureau of Resource Sciences is a professionally independent scientific bureau within the Department of Primary Industries and Energy. Its mission is to enhance the sustainable development of Australia's resource industries by providing high quality scientific and technical advice to government, industry and the community.

Cover photograph: A southeastern view inside the northern end of the Centurion Pit at Croesus Mining N.L.'s Binduli gold project, Western Australia. The drilling rig at the left of the picture intersected 30 metres of mineralisation with a gold grade of 26.1 grams/tonne. Photo courtesy of Bill McKay and published with the permission of Croesus Mining N.L.

Cover inset photographs: Super Pit and Mount Charlotte gold operations at Kalgoorlie. Photos courtesy of Kalgoorlie Consolidated Gold Mines.

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pages v, 1: The Super Pit, Kalgoorlie—photographs courtesy of Kalgoorlie Consolidated Gold Mines.

p. 25: Geologist inspecting iron ore outcrop—photograph courtesy of Hamersley Iron Pty Ltd.

p. 31: Thin section of rock from the Fairbridge Volcanics in the highly prospective Lachlan Fold Belt, New South Wales—photograph courtesy of Stuart Girvan, Bureau of Resource Sciences.

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Foreword

The Bureau of Resource Sciences (BRS) was established within the Department of Primary Industries and Energy in October 1992 as a recognition, by the Government, of the need for better use of scientific research and analysis in formulating public policy in the increasingly important area of resource management. The BRS mission is:

> *To enhance the sustainable development of Australia's resource industries by providing high quality scientific and technical advice to government, industry and the community.*

BRS is responsible for providing independent advice and analysis on Australia's inventory of identified mineral resources, their rate of development and the level of exploration activity. To ensure that policy makers, the mining industry, the investment sector and the general community are well informed on these matters, the Mineral Resources and Energy Branch produces *Australia's Identified Mineral Resources* annually, drawing on current and historical data from mining and exploration companies.

BRS maintains two national minerals databases: MINRES, which contains information on the quantity, quality, type, and location of over 2300 mineral deposits; and MINLOC, which contains detailed locations for over 47 000 Australian mineral occurrences. These are being linked to OZMIN, an Australian Geological Survey Organisation database listing the geological features of mineral deposits.

BRS also underpins government policy and management decisions by appraising the mineral resource potential of areas being considered for restricted land use, advising on environmental issues in the context of resource assessment, and providing advice on offshore exploration and mining technologies.

BRS has released MINLOC and MINRES commercially, and undertakes independent work for external clients, including:

- audits of mineral resources;
- financial modelling of mineral projects;
- development of innovative geographic information systems for resource management;
- advising on mineral resource developments in emerging nations;
- appraisals of mineral resources potential; and
- integrated analyses of diverse data and information in the context of environmental protection and sustainability of mining.

Peter O'Brien
Executive Director
Bureau of Resource Sciences

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Abbreviations and acronyms

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
AGSO	Australian Geological Survey Organisation
BMR	Bureau of Mineral Resources, Geology and Geophysics
BRS	Bureau of Resource Sciences
c	carat
c/t	carat per tonne
EAR–1	estimated additional resources – category 1
EDR	economic demonstrated resources
GL	gigalitre
Gt	gigatonne
IAEA	International Atomic Energy Agency
km	kilometre
kt	kilotonne
L	Litre
m	metre
m^3	cubic metre
Mc	million carats
MEL	mineral exploration licence
MREB	Mineral Resources and Energy Branch
Mt	million tonnes
Mtpa	million tonnes per annum
na	not available
NSW	New South Wales
NT	Northern Territory
OECD/NEA	Organisation for Economic Cooperation and Development/Nuclear Energy Agency
PGM	platinum group metals
Qld	Queensland
RAB	rotary air blast
RAR	reasonably assured resources
RC	reverse circulation
$	dollar
SA	South Australia
t	tonne
Tas	Tasmania
U	uranium
U_3O_8	uranium oxide
USA	United States of America
USBM	United States Bureau of Mines
US$	United States of America dollar
Vic	Victoria
WA	Western Australia
WEC	World Energy Council

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 small 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.

COMMODITY REVIEW

Summary

The Australian mineral industry is an integral part of the domestic economy with $30.3 billion (thousand million) being generated in export earnings in the 1994–95 fiscal year. As in 1993–94, export earnings from minerals in 1994–95 were just over 60% of the earnings from all commodity exports for the year. The Australian Bureau of Agriculture and Resource Economics (ABARE) forecast that earnings from mineral exports will be $34.6 billion in 1995–96. Without Australia's large and diverse mineral resource base such a major contribution to the economy would not have been possible.

Australia ranks as one of the world's leading mineral resource nations. According to estimates published by the United States Bureau of Mines (USBM), Australia is one of the world's top five countries for resources of bauxite, bismuth, cadmium, industrial diamond, gold, mineral sands, lead, lithium, manganese, rare earth oxides, silver, tantalum, and zinc. Australia has the world's fifth largest economic resources of brown coal and the sixth largest of black coal, and has the world's largest low cost uranium resources.

In 1995, Economic Demonstrated Resources (EDR) for gold increased substantially and those for bauxite, ilmenite, rutile, zircon, and nickel increased slightly. There was a significant reduction in the EDR for tin and minor reductions for black coal, iron ore, lithium, magnesite and platinum group metals (PGM).

Exploration expenditure rose again in 1994–95 to reach $893.3 million. Gold was the main target with an expenditure of $554.5 million, which was 62% of all mineral exploration expenditure. Continued high levels of exploration are essential if Australia is to maintain its mineral resource stock to support a sustainable contribution by the sector to the economy.

Introduction

This report presents the fourth annual assessment of Australia's identified mineral resources by BRS. It continues and is consistent with the resource assessment series published annually by the former Bureau of Mineral Resources, Geology and Geophysics (BMR). It is used by policy makers, the minerals industry, and the Australian Bureau of Statistics. The data are used in annual surveys of world mineral commodities.

The assessment is undertaken as an input into government policy decisions relating to the sustainable development of mineral resources and environmental management. The report examines trends in resources of all major, and some minor mineral commodities, and comments on Australia's world ranking as a resource nation. In addition, it comments on exploration expenditure (in current dollars) in the 1994–95 and the previous three fiscal years. The current level of expenditure is put into perspective by comparing it in real terms to expenditure over the preceding 24 years.

Estimates of Australia's identified resources of all major and several minor

mineral commodities are reported for 1995 (Table 1). The estimates, prepared by the Mineral Resources and Energy Branch (MREB) of BRS, are based on published and unpublished data available to BRS up to the end of December 1995. Mine production for Australia reported in Table 1 was provided by the ABARE and data on 1994–95 production and exports are from ABARE (1995). Data on petroleum resources were provided by the Petroleum Resources Branch of BRS. World data have been obtained or calculated from data in various sources but mainly in publications of the USBM.

The mineral resource classification used in this report was adopted by BMR in 1975 (BMR 1976) and refined in 1983 (BMR 1983). It reflects both the geological certainty of existence of the mineral resource and the economic feasibility of its extraction (see Terminology and definitions). The term EDR is used instead of 'reserves' for national totals of economic resources because the term 'reserve' has various meanings that are not always consistent. EDR also provides a basis for meaningful international comparisons of the economic resources of other nations. With few exceptions, ore is mined from resources in the EDR category. EDR are reduced by mining and increased by new discoveries and by technical and economic changes which allow formerly subeconomic deposits to be reclassified as economic.

BRS has prepared estimates of Australia's uranium resources within categories defined by the OECD Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA) (OECD/NEA & IAEA 1996). In this publication these estimates are reported under the corresponding resource categories of the BRS classification scheme. A correlation of the BRS and OECD/NEA schemes is given in the review of uranium resources.

Long-term trends in EDR for bauxite, black coal, iron ore, gold, copper, lead, zinc, nickel, and mineral sands are shown in Figure 1. EDR for these commodities have increased or at least been maintained since 1975 despite substantial levels of production. Much of the success in maintaining EDR can be attributed to the sustained exploration activity that Australia has enjoyed over the period.

Bauxite

Australia's bauxite resources remained relatively unchanged in 1995 compared with those of the previous year. Bauxite EDR constitute approximately 33% of demonstrated resources and 26% of identified resources (demonstrated plus inferred resources).

The resources at Weipa, Queensland, and in the Darling Range, Western Australia, continue to rank among the world's largest bauxite deposits in terms of extractable alumina content. In the Northern Territory, the life of the Gove bauxite mine has been extended to about 2030 by a decision to mine bauxite reserves of marginally different grades. Australia's production of bauxite and alumina is forecast to increase by 3.9% and 2.0% over the 1995 levels to 44.1 Mt and 13.2 Mt respectively in 1995–96 (ABARE 1996). Bauxite production at Weipa was lower than in 1994 due to problems

Table 1 Australia's identified resources of major minerals and fuels, 1995, and world figures for 1994

COMMODITY	UNITS	AUSTRALIA							WORLD 1994	
		Demonstrated			Inferred			Mine production 1994	Economic demonstrated resources (l)	Mine (a) production
		Eco-nomic	Subeconomic		Eco-nomic	Sub-econo mic	Undifferent-iated			
			Para-marginal	Sub-marginal						
Antimony	kb Sb	97.9	33.8	36.3	18.8	0.1	16.7	0.9	4200	106
Asbestos										
Chrysotile ore	Mt	-	46.24	-	-	-	75.18	-	large	} 2.41 (k)
Crocidolite fibre	Mt	-	0.37	-	-	-	2.12	-	large	
Bauxite	Mt	2540	-	5245	-	-	2134	42.2	23000	107 (b)
Black coal										
In situ	Gt	68	2	6	-	-	very large			
Recoverable	Gt	49	2	4	-	-	-	0.24 (c)	708	3.6 (d)
Brown coal										
In situ	Gt	46	1	2	-	-	184			
Recoverable	Gt	41	1	2	-	-	166	0.049	315	0.93
Cadmium	kt Cd	140.7	11.3	15.2	31.4	0.1	-	1.9	540	18.1
Chromium	kt Cr	-	55.5	207.8	-	1623.8	-	-	3700000	9570
Cobalt	kt Co	274	231	99	80	147	0.8	0.4	4000	18.5
Copper	Mt Cu	24	14.7	1.6	2.5	9.4	-	0.4	310	9.4
Diamonds										
Gem & near gem	10^6 c	101	156	1.3	2.1	-	39	} 43.8	300	55.9
Industrial	10^6 c	128	190	5.4	-	-	61		980	58.7
Fluorine	Mt F	-	24.11	5.78	-	-	0.68	-	102 (i)	1.88
Gold	t Au	4263	1100	48	-	-	1378	255	44000	2300
Iron ore	Gt	17.8	13.8	0.4	-	-	17.2	0.128	150	1
Lead	Mt Pb	18.2	4.8	8.9	5.2	10.8	2	0.5	63	2.8
Lithium	kt Li	152	-	3	-	-	7	3.0	2200	7.4 (b)
Magnesite	Mt-$MgCO_3$	241.3	-	294.1	-	-	230	0.29	2500	2.47 (b)
Manganese ore	Mt	121.2	27.1	167	70.5	96.1	-	1.99	2000	20.2
Mineral sands										
Ilmenite	Mt	135.8	67.2	0.1	-	-	99.1	1.8	574.7	6.0 (b)
Rutile	Mt	15.0	33.4	0.2	-	-	26.3	0.23	42.03	0.5 (b)
Zircon	Mt	22.5	24.2	0.2	-	-	20.9	0.51	62.05	0.89 (b)
Molybdenum	kt Mo	-	4.7	3.2	-	-	832.6	-	5500	104
Nickel	Mt Ni	3.7	3.6	2.8	-	-	4.4	0.076	47	0.906
Niobium	kt Nb	3.4	67.6	-	-	-	1994	-	3500	15
Petroleum (recoverable) (e)										
Crude oil	GL	297	-	29	-	-	-	27.1	158844	3506
Natural (sales) gas	$10^9 m^3$	1292	-	1249	-	-	-	28.3 (f)	} 142042	2207
Condensate	GL	156	-	65	-	-	-	4.0		
LPG naturally occur.	GL	154	-	90	-	-	-	3.7		
Phosphate rock	Mt	-	2095	-	-	-	1947	0.003	11000	128
PGM (Pt, Pd, Os, Ir, Ru, Rh)	t metal	17.2	17.0	6.8	3.5	77.8	-	0.5	56000	227.2 (j)
Rare earths										
REO and Y_2O_3	Mt	1	3.5	10.6	-	-	4.0	-	100	0.07
Shale oil	GL	-	-	4564	-	-	40468	-	na	na
Silver	kt Ag	41.5	9.8	11.1	8.8	9	8.3	1.05	280	13.9
Tantalum	kt Ta	6.2	5.5	0.1	-	-	65.1	0.2	22	325
Tin	kt Sn	136.2	46	143	-	339.2	5.3	7.4	7000	180
Tungsten	kt W	1	34.1	28	2.5	177.6	-	0.04	2100	26
Uranium (g)	kt U	629	-	77	154	40	-	2.208	2120 (h)	31.448
Vanadium	kt V	15	1739	8425	-	2282	-	-	10000	33.9 (b)
Zinc	Mt Zn	38.8	13.6	11.3	11.6	9.2	1.5	1.0	140	6.8

Abbreviations: t = tonne; c = carat; m^3 = cubic metre; L = litre; kt = 10^3t; Mt = 10^6t; Gt = 10^9t; GL = 10^9L; REO = rare earth oxide

(a) World mine production figures for 1994 are estimates.
(b) Excludes USA.
(c) Raw coal.
(d) Saleable coal.
(e) Source: Petroleum Resources Branch, BRS (as at 31 Dec 1994).
(f) Includes ethane.
(g) Refer to text for comparison of resource categories in the BRS scheme with those of the international scheme for classifying uranium resources.
(h) Source: OECD/NEA and IAEA (1996).
(i) Excludes USA and Brazil.
(j) Platinum and palladium only.
(k) Includes crocidolite production.
(l) Based on BRS, USGS and other sources.

Table 1 Australia's identified resources of major minerals and fuels, 1995, and world figures 1994

		AUSTRALIA							WORLD 1994	
		Demonstrated			Inferred					
		Economic	Subeconomic		Economic	Sub-economic	Undifferent-iated	Mine production 1994	Economic Demonstrated Resources[l]	Mine[a] production
			Para-marginal	Sub-marginal						
Antimony	(kt Sb)	97.9	33.8	36.3	18.8	0.1	16.7	0.9	4200	106
Asbestos										
Chrysotile ore	(Mt)	—	46.24	—	—	—	75.18	—	large }	2.41[k]
Crocidolite fibre	(Mt)	—	0.37	—	—	—	2.12	—	large }	
Bauxite	(Mt)	2540	—	5245	—	—	2134	42.2	23000	107[b]
Black coal	(Gt)									
in situ		68	2	6	—	—	very large			
recoverable		49	2	4	—	—	—	0.24[c]	708	3.6[d]
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Copper	(Mt Cu)	24	14.7	1.6	2.5	9.4	—	0.4	310	9.4
Diamonds	(10^6 c)									
gem and cheap gem		101	156	1.3	2.1	—	39 }	43.8	300	56.9
industrial		128	190	5.4	—	—	61 }		980	58.7
Fluorine	(Mt F)	—	24.11	5.78	—	—	0.68	—	102(i)	1.88
Gold	(t Au)	4263	1100	48	—	—	1378	255	44000	2300
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Condensate	(GL)	156	—	65	—	—	—	4.0 }	142042	2207
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Phosphate rock	(Mt)	—	2095	—	—	—	1947	0.003	11000	128
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Rare earths										
REO and Y_2O_3	(Mt)	1	3.5	10.6	—	—	4.0	—	100	0.07
Shale oil	(GL)	—	—	4564	—	—	40468	—	na	na
Silver	(kt Ag)	41.5	9.8	11.1	8.8	9	8.3	1.05	280	13.9
Tantalum	(kt Ta)	6.2	5.5	0.1	—	—	65.1	0.2	22	325
Tin	(kt Sn)	136.2	46	143	—	339.2	5.3	7.4	7000	180
Tungsten	(kt W)	1	34.1	28	2.5	177.6	—	0.04	2100	26
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(a) World mine production figures for 1994 are estimates
(b) Excludes USA
(c) Raw coal
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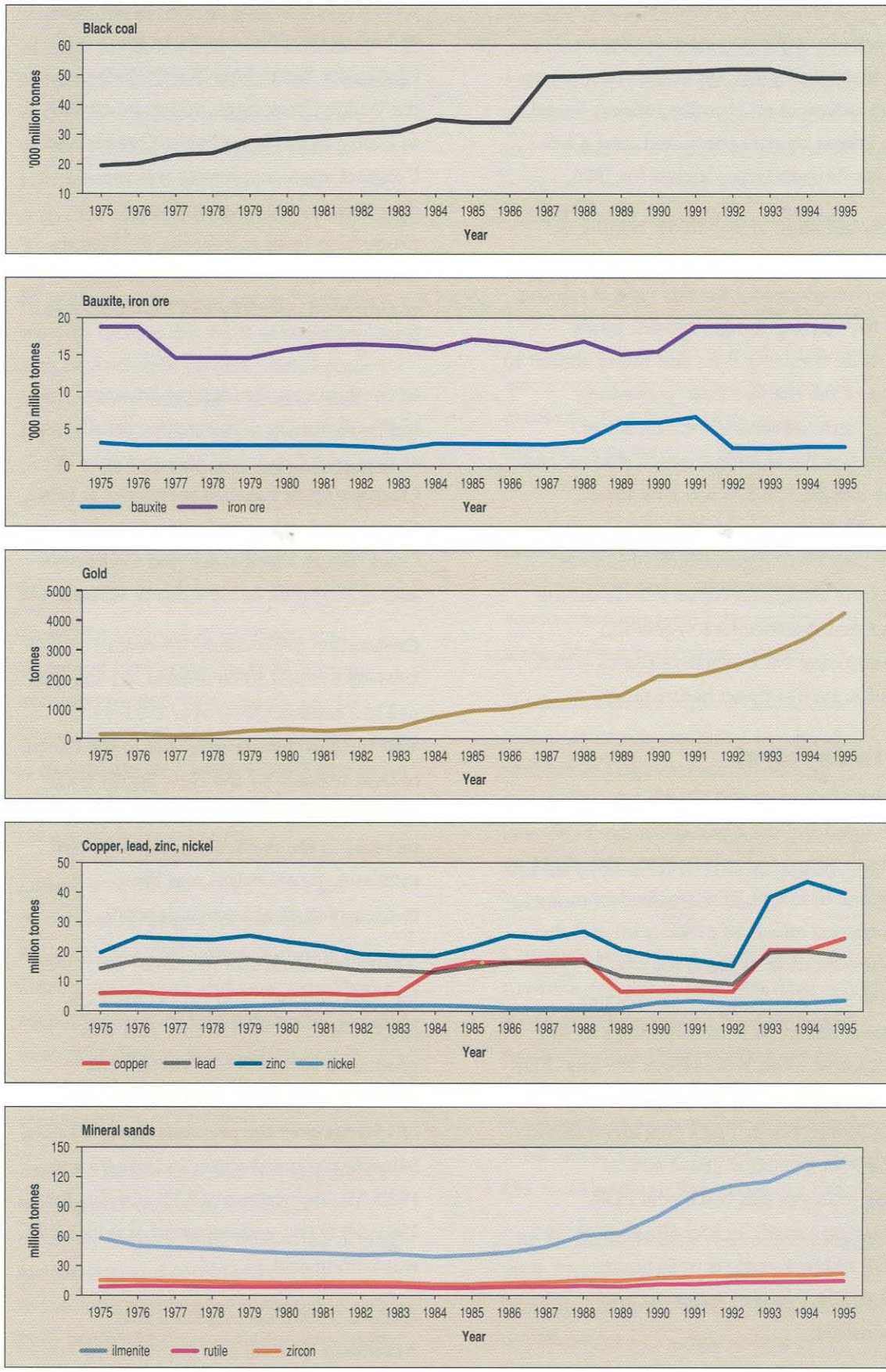
(j) Platinum and palladium only
(k) Includes crocidolite production
(l) Based on BRS, USGS and other sources

Figure 1 Trends in economic demonstrated resources (EDR) for major commodities since 1975



with equipment. In addition, metal grade bauxite shipments were disrupted by a blockade of Weipa's port during an industrial dispute late in the year. Evaluation of an alumina refinery based on Weipa bauxite continued, and a full feasibility study is planned for 1996.

Rehabilitation after bauxite mining in Australia is now widely regarded as a benchmark model for this type of mining. In the Darling Range, specific goals include restoring flora and fauna similar to that of the native forest, preventing long-term adverse effects on water supplies, controlling dieback disease and fire hazards, and in some localities establishing recreational areas. At Weipa, the long-term regeneration objectives include establishment of self-sustaining and maintenance-free vegetation comprising various native plants which will in turn support native fauna.

Black coal

Australia's in situ EDR of black coal declined slightly but recoverable EDR remained unchanged in 1995. The slight decline in in situ EDR resulted from the combined effects of production and the reclassification of some resources. New South Wales and Queensland accounted for 97% of Australia's in situ black coal EDR, with 44% of the total EDR occurring in the Sydney Basin and 34% in the Bowen Basin. Black coal amenable to open-cut mining is about 40% of Australia's in situ black coal EDR. Relatively small, but locally important, EDR of black coal occur in South Australia, Western Australia and Tasmania.

During 1995, the first shipments of coal were made from the new Stratford mine, 95 km north of Newcastle, in the Gloucester Basin, New South Wales, and the Wilkie Creek mine, 40 km northwest of Dalby, in the Surat Basin, Queensland. Contract open-cut mining at these operations is the first significant coal production from each basin. In Western Australia, the Premier open-cut mine commenced operations in the Collie Basin during 1995.

In continuing technological advance, highwall mining is being successfully used at the Oaky Creek and Moura mines in Queensland. It has also been used at other Queensland mines including German Creek, South Blackwater, and Collinsville, and at Foybrook in New South Wales.

Exploration expenditure for coal in 1994–95 totalled $38.0 million, an increase of $10.3 million (37%) over 1993–94. This increase was largely due to the effects of land releases by the New South Wales and Queensland Governments, a projected increase in the demand for thermal coal, increases in coal prices and the re-examination of known deposits.

Australian black coal resources are mined for both domestic and export markets. In 1994–95, 236.8 Mt of raw coal was produced, 72% of which came from open-cut operations. This was an increase of 15.0 Mt over the previous financial year. Saleable coal production in 1994–95 was 192.3 Mt, an increase of 8.1%. Of this total, 136.9 Mt (71%) was exported of which 54% was coking coal.

ABARE (1996) has projected that Australian thermal coal exports will

increase by 55% to over 110 Mt in 2000–01. In total, Asian countries are forecast to account for around 80% of Australian thermal coal exports in 2000–01. Australia is expected to supply half of Asia's thermal coal imports in that year. In anticipation of an increase in coal exports, port expansions are planned in both New South Wales and Queensland.

In 1994, Australia had about 7% of the world's recoverable EDR of black coal, and was ranked sixth behind USA, former USSR, China, India and South Africa. Also in 1994, Australia produced about 5% of the world's saleable black coal output and was ranked sixth after China, USA, former USSR, India and South Africa.

Brown coal

Australia's resources of brown coal remained unchanged in 1994. Victoria accounts for 94% of Australia's in situ brown coal EDR and 86% of the total EDR is in the Latrobe Valley. Brown coal is mined only in Victoria and is used mainly for electricity generation.

During 1995, there were significant operational changes for the three Latrobe Valley brown coal mines. Yallourn Energy, Hazelwood Power and Loy Yang Power each now own and operate their own mine to supply their power stations which generate electricity for Victorian consumers.

Brown coal research and development by the Herman Research Laboratory is currently investigating integrated drying, gasification and combined cycle technology that has the potential to reduce both greenhouse gas emissions and costs.

In 1994, Australia had about 13% of the world's recoverable EDR of brown coal, and was ranked third behind the former USSR and Germany. Australia produced about 5% of the world's brown coal output in 1994 and, as a producer, ranked seventh after Germany, former USSR, USA, Poland, Czech Republic and Greece.

Chromium

This year, for the first time, BRS reports Australia's resources as total chromium resources, rather than as resources of chromite. The change was made for two important reasons: the relative importance of lateritic deposits in Australia where chromium is associated with iron oxide minerals and does not occur as chromite; and to enable easier comparison with world resources which are reported in terms of their chromium content.

Australia's demonstrated chromium resources are concentrated in a small number of large deposits including Coobina and the Range Well lateritic chromium deposit in Western Australia and the polymetallic, lateritic resource at Syerston in New South Wales.

Chromite was mined in a trial at the Coobina deposit in late 1995. This was the first time chromite had been mined in Australia since 1988. A 6000 t ore parcel was produced from the deposit for assessment at a ferro-alloy plant. Coobina is owned jointly by Valiant Consolidated Ltd and Danelagh Resources Pty Ltd.

Chromiferous laterite resources at Range Well, 67 km north-northwest of Cue, Western Australia, have potential for development as a single source of

chromium and iron for alloys used as grinding media in mineral processing. The feasibility of the Range Well project is being investigated.

Australia's identified chromium resources constitute a tiny fraction of world identified chromium resources which are about 7.4 Gt.

Copper

The 1995 EDR estimate of 24 Mt of copper is 16% (4 Mt) higher than the estimate from the last major assessment, undertaken in 1993. Identified resource stocks of copper increased by 13% (6 Mt).

In New South Wales, the Cadia deposit added significantly to EDR, as did the Northparkes and Girilambone deposits. The Ernest Henry and Osborne deposits in Queensland also contributed to the growth in EDR but these gains were offset by decreases at the more mature Mt Isa and Mammoth mines. Other significant contributions were from the Mt Lyell (Tasmania) and Gecko (Northern Territory) deposits that were mined in the past and have been reactivated recently. Exploration around the old Mt Gunson deposits (South Australia) has defined EDR in new and remnant copper–cobalt resources.

Large resources of low grade gold–copper mineralisation delineated in the Cadia Hill and Cadia East deposits in central New South Wales are undergoing a preliminary feasibility study, and an environmental impact statement is being prepared.

At Northparkes, Probable Reserves were increased by 30% in the Endeavour 26N and 48 deposits as a result of a drilling program completed in May 1995 and a reduction of cut-off grade from 1.2% to 0.8% copper equivalent. Treatment of sulphide copper–gold ore commenced in September 1995 after oxide gold ore processing and bullion production were completed in August. Development of the haulage shaft and service decline continued in preparation for mining by low-cost block caving in 1997. This method involves excavating a void below the ore to be mined, so that the ore falls by controlled collapse from the roof. The ore is removed through draw points (openings) in the floor of the void. Northparkes will be the first modern operation in Australia to use this technique.

Production from the large open pit resources at the Ernest Henry copper–gold–cobalt deposit near Cloncurry is scheduled to start in late 1997. Further south at Osborne, open pit mine production of oxide and primary ore commenced in August 1995 after development costing of $156 million. An additional $65 million is being spent on underground mining development. Expected production for 1996 is 36 000 t of copper and 55 000 ounces of gold from 1 Mt of ore.

Company evaluation of the remaining resources at the Mt Lyell deposit in Tasmania confirmed 207 Mt of mineralisation containing 1.3 Mt of copper. Underground mining commenced in 1995 on the 70 Series ore, about 700 metres below surface. The 70 Series decline progressed and will provide access for drilling of the resource to about 1200 metres depth. Refurbishment of the processing plant and underground crusher

Photograph courtesy of Western Mining Corporation Ltd.

Plate 1 Underground drilling at the Olympic dam copper–uranium–gold mine, South Australia.

was completed, and an automatic hoisting system commissioned. The mine was officially re-opened on 15 December 1995 and the first shipment of 10 000 t of concentrate was scheduled to leave Burnie in March 1996. A minimum 10 year mine life is expected to produce 300 000 t of copper and 250 000 ounces of gold.

Recommissioning of the Gecko copper–gold mine and Warrego concentrator took place in early 1995. Evaluation of other old mines and resources is ongoing around Tennant Creek. Additional copper–cobalt resources have been delineated in and around the old Mt Gunson copper mine in South Australia. Feasibility studies suggest a target mining rate of about 1 Mtpa to produce 7500 t of contained copper and 500 t of contained cobalt over 13 years.

Despite ongoing production, copper EDR trends since 1975 (Figure 1) show a relatively low, sustained level until the mid 1980s when EDR more than tripled because of new resources defined at the Olympic Dam deposit in South Australia. Over the last two decades Australia's stock of identified copper resources has been maintained at more than twice the EDR level. Calculated potential production from EDR was steady at 25 to 30 years until 1984 when a rise to 50 to 60 years was recorded. This level is maintained today.

The discovery of the Olympic Dam deposit and, more recently, deposits such as Ernest Henry, Osborne, Cadia and Northparkes, were the result of exploration using modern techniques and having access to large tracts of Australia for low impact reconnaissance exploration. Subsequent detailed exploration was done over very limited areas and these deposits were ultimately shown to underlie, in

total, less than 20 square kilometres of land. Continued access for low impact exploration is essential to maintain and increase Australia's copper resources position.

Australia has the world's third largest EDR of copper (9%), after Chile (28%) and USA (15%). As a copper producer, Australia ranks fifth in the world. Production is mainly from mines at the Olympic Dam, Mount Isa, Northparkes, Osborne and Mt Lyell deposits.

Diamond

Australia's EDR for gem/near gem and industrial diamond fell by 29 million carats (Mc) and 40 Mc respectively. Compared with the 1994 assessment, which was based on end of 1993 data, the new EDR, based on end 1995 data, was 20% lower for each category of diamond. Identified resources of both gem/near gem and industrial diamond were respectively 4.2 Mc and 4.5 Mc lower than the 1994 assessment. Total production of diamond for 1993 and 1994 was more than 80 Mc.

Much of the reduction in EDR was the result of production at the Argyle Pipe mine which was only partially offset by the upgrading of some subeconomic resources. The smaller decrease in total resources reflects the addition of significant resources to the inferred category. These and other new resources were identified beneath the Argyle Pipe open pit. The feasibility of underground mining is still being studied and the medium to long term future of the mine will depend on the outcome of this study.

Australia diamond production in 1994 was a record 43.8 Mc. It was largely from the Argyle Pipe mine with minor contributions from the nearby Argyle Alluvials mine and the Bow River operation.

The processing plant capacity at Argyle was raised by 2 Mt per year. In 1995, diamond recovery was about 85% for the Argyle Pipe mine and 90% for the Argyle Alluvials mine. The minimum stone size recovered at the Argyle Pipe plant was increased by replacing the 1 mm lower cut sifting screens with screens that retain 1.5 mm or larger diamonds. Although this resulted in a lower overall diamond output, value was higher than last year. Hydro-electricity supply from Lake Argyle to these mines is to be commissioned in 1996.

At the Bow River alluvial operation, about 30 km northeast and downstream of Argyle, agreement was reached in February 1995 under State Aboriginal Heritage Legislation to resume mining in areas closed in October 1994. Delineation of Aboriginal heritage sites in other exploration and mining areas commenced in May 1995. Reduced cost projections resulted in some subeconomic resources being re-classified to EDR and this extended operations until 1 December 1995 when the last accessible economic resources were fed to the processing plant. Exploration success was limited on leases to the southeast of the mine and incremental additions made to EDR in the mine area were insufficient to extend mine life. After some tailings retreatment the mine and plant were put on care and maintenance. As with many mines, the

final amount of ore treated significantly exceeded (by 130%) the economic resources delineated at the start of mining operations.

Bulk sampling of the Merlin cluster of diamondiferous kimberlite pipes is ongoing and some continue to show possible commercial potential. Of eleven kimberlite pipes identified so far, eight have grades over 0.2 carats/tonne (c/t) and three of these are over 0.45 c/t. Bulk sampling of the Palomides pipe by wide diameter drilling and a 1000 t underground sample (shaft and 2 drives at 36 metres depth) yielded a parcel of diamonds valued at an average of US$60 per carat. This is about six times the average carat value of the much larger and higher grade (over 3 c/t) Argyle Pipe deposit. The Excalibur pipe is the next underground deposit to be bulk sampled. Several new prospects with micro-diamonds and kimberlite indicator minerals have been located in the Merlin region and 45 targets have been selected for drilling at the Dog Leg Creek prospect to the southeast.

Australia has the world's second largest EDR of industrial diamond and probably the largest for gem/near gem diamond. Australia's diamond production is the largest in the world for both gem/near gem and industrial categories.

Gold

1995 was a successful year for the gold exploration industry in that substantial additions were made to resources despite continued high levels of production. There was some evening out of the distribution of EDR across States, although Western Australia remained predominant. Ownership of EDR is highly concentrated; however, there are a very large number of companies exploring. Exploration expenditure for gold in 1994–95 rose substantially. On the world scene, Australia remained the third largest holder of EDR and the third largest producer.

Substantial growth was again recorded in the level of Australia's EDR of gold. The 1995 estimate of 4263 t is 24% higher than the 1994 level. Subeconomic demonstrated resources fell by 139 t to 1149 t, a reduction of 11%. Inferred resources rose by 5% to 1379 t. These figures translate to an overall increase of 752 t in Australia's stock of identified gold resources in 1995 compared with 1994.

EDR was 63% of identified resources compared to 57% in 1994. In contrast the share of subeconomic resources fell from 21% to 17%. The share of inferred resources fell from 22% to 20%. The increased proportion of resources in the EDR category is largely attributable to successful exploration at projects in or nearing production.

With the exception of South Australia, which remained unchanged, all States and the Northern Territory saw increases in EDR in 1995. Western Australia remained the leading State with 58% of Australia's EDR. Queensland, New South Wales and the Northern Territory all have EDR of similar magnitude, which together account for 26% of Australia's EDR. The remaining 16% occurs in Victoria, South Australia and Tasmania.

Eighteen projects, with more than 50 t of gold in EDR, account for 59% of

Australia's total EDR. Although there are over 450 companies with direct gold exploration or production interests in Australia, this 59% of EDR is controlled by only 16 companies. Fifteen of these projects are in production, and seven have EDR in excess of 100 t each and the EDR of those seven accounts for 41% of Australia's EDR. Within the group of 18 projects, five companies hold just over 1702 t or 40% of Australia's EDR. If the EDR of those five companies included projects with less than 50 t EDR, their total share would be greater still.

Photograph courtesy of Kalgoorlie Consolidated Gold Mines Pty Ltd.

Plate 2 Revegetated noise bund between the Super Pit gold mine and the town of Kalgoorlie.

Photograph courtesy of Kalgoorlie Consolidated Gold Mines Pty Ltd.

Plate 3 The Super Pit gold mine at Kalgoorlie works one of Australia's most important gold resources.

Exploration expenditure for gold reported by ABS in 1994–95 was $554.5 million or 62% of the total Australian expenditure on mineral exploration of $893.3 million. The 1994–95 expenditure was an increase of 22% over the previous year. Western Australia was the leading State with $379.4 million (68.4% of the total) spent on the search for gold. The proportion of the gold exploration budget spent in Western Australia was similar to that in 1993–94. It was followed by Queensland (10.8%), Northern Territory (7.8%), New South Wales (7.5%), Victoria (4%), South Australia (1%) and Tasmania (0.5%). ABS figures for the first half of 1995–96 show exploration expenditure of $272.2 million, $9.5 million less than for the first half of 1994–95. If the price of gold remains at or above its 1995 levels, and other conditions are unchanged, exploration expenditure should continue to remain high. This can be expected to result in further increases in resources.

ABARE reported Australia's mine production of gold in 1994–95 was 248.6 t, a reduction of 3% over the record output of 1993–94. Despite this reduction, ABARE (1996) forecast that output in 2000 will reach 360 t, a 45% increase from the 1994–95 level. The distribution of Australia's known EDR suggests that this level of production will be difficult to achieve by 2000. Maintenance of high levels of exploration expenditure and access to prospective land will, however, increase the possibility of new discoveries that will help support higher production.

Internationally, Australia has the world's third largest stock of gold EDR after South Africa and the USA. It has approximately 10% of world EDR on the basis of estimates by the USBM. Australia is also the world's third largest producer of gold, again after South Africa and the USA. In 1994 it maintained its share of world output at 11%.

Iron ore

Australia's EDR of iron ore fell by less than 1% in 1995. The reduction was entirely due to production. Resources in the subeconomic demonstrated categories and inferred category were unchanged. EDR is currently just over 36% of Australia's identified resources and subeconomic demonstrated resources are 35%.

Western Australia has over 99% of Australia's EDR. Of the Western Australian EDR, some 97% occurs in the Hamersley Basin in the Pilbara region. Smaller, but important, economic resources occur and are worked in South Australia and Tasmania.

A significant exploration program is under way in South Australia aimed at delineating resources that may be used in conjunction with coal from the Arkaringa Basin to further develop the State's iron and steel industry.

Based on estimates published by the USBM, Australia has the equal second largest EDR of iron ore with the USA, after Russia. However, using the USBM estimates for other countries and the BRS assessment of Australia's EDR, Australia has 12% of world EDR and is ranked second after Russia. If EDR is considered in terms of contained iron, Australia is still second after Russia but its share of resources rises to just over 17%.

Australia's level of production of iron ore ranks it fourth after Russia, China and Brazil, and accounts for about 13% of world output.

Lithium

New lithium resource estimates for Australian deposits were not published during 1995. However, BRS has reviewed Australia's resources and production since the last published company resource estimates. This resulted in a small reduction of EDR to 152 kt contained lithium. The reduction is attributable to production from the Greenbushes operation in Western Australia. Subeconomic and inferred resources remained unchanged. Gwalia Consolidated Limited report that its Greenbushes lithium resource is the largest and highest grade spodumene ($Li_2O.Al_2O_3.4SiO_2$) deposit in the world.

Gwalia is a major supplier of lithium mineral concentrates to the world market. These are used in ceramics and glass manufacture and as the raw material for the production of value added lithium chemicals and lithium metal. The various chemicals and metal have a range of applications including in air conditioning units, colour film processing, polymers, alloys and batteries. Commissioning of a lithium carbonate plant at Greenbushes was continuing at the end of 1995. Gwalia will initially produce 1600 t of lithium carbonate a year, increasing to 5000 t a year. Lithium carbonate is used in ceramics and specialty glass and in aluminium smelting and continuous casting of steel.

Estimates published by the USBM for Australia's 'reserves' substantially overstate Australia's EDR. However, if the USBM estimates for other countries are accepted and Australia's EDR as published here is substituted, Australia would have just under 7% of world EDR and would be ranked fourth after Chile, USA and Canada. In terms of production, Australia ranks second after Chile, accounting for about 41% of world (excluding the USA) output.

Manganese ore

Australia's EDR decreased by 2% in 1995 compared with 1994. This reflected a minor diminution in resources at Groote Eylandt, Northern Territory, because of mining, and also a reclassification of some relatively small manganese ore resources in the Woodie Woodie area, Western Australia. The decline in Australia's EDR since 1975 has resulted from the reclassification of resources in the 1980s when more detailed information became available, and because of resource depletion as a result of mining.

The principal Australian mine and manganese resources are on Groote Eylandt, where a large world-class deposit is being mined for domestic consumption and export, at the rate of about 2 Mt of manganese ore a year. Significant mining of manganese ore continued in the Woodie Woodie area in the east Pilbara of Western Australia where operations by Portman Mining Limited resumed in 1995, producing and exporting high grade manganese oxide. The new Mike mine south of Woodie Woodie, operated by Valiant Consolidated Limited, continued

open-pit mining during the year and produced high grade manganese ore with low impurities for export.

Australia's resources of manganese ore underpin a major mineral export sector as well as a significant domestic ferromanganese, silicomanganese and manganese dioxide processing industry.

In 1995 Australia accounted for about 6% of the world's EDR of manganese ore and was ranked third after South Africa (50%) and Ukraine (18%). In terms of contained manganese, Australia's share of world economic resources was 13%. Australia produced 14% of world manganese ore output in 1994 (in terms of contained manganese) and is the third largest producer behind South Africa and Ukraine. Australia was the second largest exporter of manganese ore after Gabon in 1994.

Mineral sands

EDR of ilmenite, rutile and zircon increased by 2%, 4% and 7% respectively in 1995. Western Australia has about 50% of rutile and zircon, and over 70% of ilmenite EDR. Exploration in western New South Wales resulted in an increase in EDR of zircon and rutile in that State. The upgrading of previously inferred resources in the Northern Swan Coastal Plain of Western Australia contributed to an overall increase in EDR of zircon in 1995.

Over 40% of the EDR of rutile and over 30% of zircon EDR in Queensland and New South Wales are unavailable for mining. Areas quarantined from mining are now largely incorporated into national parks. They include Moreton, Bribie and Fraser Islands, Cooloola sand mass north of Noosa, and the Shoalwater Bay area in Queensland, and Yuraygir, Bundjalung, Hat Head and Myall Lakes National Parks in New South Wales.

Photograph courtesy of Valiant Consolidated Ltd.

Plate 4 An aerial view of the Mike Manganese project in the Pilbara region of Western Australia.

With the expectation of improved demand for titanium dioxide pigment, the principal end use for ilmenite and rutile, and the continuing strong demand for zircon by the ceramic and refractory industries, the Australian mineral sands industry is operating at near full capacity. BHP Titanium's Beenup mine in southwest Western Australia is expected to commenced production in 1997. RZM Pty Ltd is evaluating a new deposit in southwest New South Wales with the aim of commencing a new mine in the next few years. Other mineral sand projects, such as Byfield, near Rockhampton, Queensland, and the WIM deposits in Victoria, are still under investigation.

Most of Australia's currently mined resources are along the east and west coasts in both modern and ancient coastal sand systems.

Along with the increase in the production of mineral sands concentrates, expansions in synthetic rutile capacity by Westralian Sands Limited at Capel and by the Tiwest Joint Venture at Muchea, and expansions in titanium dioxide pigment capacity by SCM Chemicals at Kemerton and Tiwest Joint Venture at Kwinana, near Perth, have been announced over the 12 months. Australia is the world's largest producer of synthetic rutile, with about half of the ilmenite mined upgraded to synthetic rutile (containing in excess of 92% titanium dioxide) by one of the four synthetic rutile plants, located in Western Australia.

Based a combination of USBM and BRS data, it is estimated that Australia had 24% of the world economic resources of ilmenite, and 36% each of world economic resources of rutile and zircon. It is ranked first in EDR for all three minerals, and is the world's largest producer and exporter of alluvial ilmenite, rutile and zircon. South Africa and Canada mine more ilmenite than Australia; the latter from a hard rock deposit and the former from dune sands. Both countries upgrade their ilmenite to titanium slag before export.

Molybdenum

All of Australia's molybdenum resources are subeconomic.

The largest molybdenum resources are in the inferred category, and occur at Yetholme (20 km east of Bathurst) in New South Wales, with tungsten (scheelite) mineralisation at Mount Mulgine, 230 km east-southeast of Geraldton, in Western Australia. Large inferred molybdenum resources occur with copper at Coppins Gap (40 km northeast of Marble Bar) also in Western Australia. In Queensland, resources occur at Wolfram Camp (75 km southwest of Cairns), Ben Lomond (60 km southwest of Townsville) and Maureen (40 km northwest of Georgetown), the latter two in association with uranium. Molybdenum resources in the Molyhill deposit in the Jervois Ranges, Northern Territory, are associated with tungsten (scheelite) mineralisation.

Molybdenum was last produced in Australia at King Island, Tasmania, in 1990 in conjunction with scheelite mining. The scheelite fines were chemically treated to produce high-grade calcium tungstate (artificial scheelite) as well as molybdenum trisulphide. Future production of molybdenum in Australia

depends largely on the economics of recovering the metal as a by-product from polymetallic deposits.

Australia's identified resources of molybdenum comprise about 2% of the world's total identified resources of 12 Mt.

Nickel

Australia's nickel EDR grew by 30% in 1995 to a record 3.7 Mt. All of the increase occurred in Western Australia, where nickel mineralisation occurs either as massive or disseminated sulphides or as lateritic nickel deposits. This growth reflects successful exploration programs in recent years, and the reclassification of some resources into EDR. The reclassification was based on improved nickel prices.

Australian nickel production is centred on mines at Kambalda, Leinster and Forrestania in Western Australia, smelting operations near Kalgoorlie, Western Australia, and refineries at Kwinana, Western Australia, and Yabulu in Queensland.

Significant discoveries in Western Australia in recent years include sulphide deposits at Silver Swan, Yakabindie, Maggie Hays, and Honeymoon Well, and lateritic nickel deposits at Bulong, Murrin Murrin, and Cawse. Many of these deposits are currently under development or undergoing detailed feasibility studies and each has the potential to produce between 10 000 and 30 000 t a year of nickel. A variety of processing technologies, including pressure acid leaching, ammonia leaching and bacterial leaching, will be used at these new developments.

Australia's share of world EDR increased to 8% in 1995, up from 6% in the previous year. As a result of successful exploration, Australia's EDR of nickel now ranks fifth in the world after Cuba, Russia, Canada, and New Caledonia, with Indonesia now sixth.

Australia's mine production of nickel was 102 000 t in 1995. This was about 11% of the world's annual mine output of nickel and placed Australia as the world's third largest producer after Russia and Canada.

Platinum group metals

EDR of platinum group metals (PGM: platinum, palladium, osmium, iridium, rhodium and ruthenium) for 1995 was 17.2 t, about half a tonne lower than that reported in 1994. Most of these economic demonstrated resources are contained in nickel sulphide deposits of the Kambalda field, Western Australia, and the remainder are at Coronation Hill in the Northern Territory.

Although there are significant resources of PGMs in Australia, most are not commercially viable. New discoveries of stratabound reef style and hydrothermal style PGM mineralisation with associated silver, gold, cobalt, nickel and copper have recently been made at Munni Munni in the Pilbara. At Range Well in the northwestern Yilgarn Block, Western Australia, Austmin Platinum Mines Pty Ltd and Dragon Mining N.L. are continuing evaluation of both the supergene and primary PGM mineralisation. At Fifield and nearby Syerston in New South Wales, substantial subeconomic resources of PGMs occur within polymetallic lateritic deposits overlying ultramafic intrusions.

Evaluation of the Syerston deposit is continuing, mainly for nickel and cobalt.

Minor production of PGMs occurs in Western Australia as a by-product of nickel mining at Kambalda. Nickel concentrates containing PGMs are smelted at Kalgoorlie and the PGMs are retained in the matte. Slags and mattes containing PGMs (mainly palladium and platinum) are exported to a refinery overseas for final recovery.

South Africa dominates PGM resources, with over 80% of world EDR and over 60% of world mine production. Australian EDR and mine production of PGMs is less than 1% of world totals.

Shale oil

Minor variations were recorded in Australia's shale oil resources in 1995. Small increases in both subeconomic demonstrated resources and inferred resources were caused mainly by more detailed information on the quantity and classification of resources becoming available.

In September 1995, Southern Pacific Petroleum N.L. (SPP) and Central Pacific Minerals N.L. (CPM) announced that they had reached agreement with Suncor Incorporated of Canada to jointly develop the Stuart oil shale deposit near Gladstone in Queensland. Under this arrangement, SPP/CPM will act as project developer and Suncor will be the operator. The development will involve scaling up from the earlier pilot plant to a Stage 1 demonstration plant at a cost of $217 million.

Greenvale Mining N.L. and Esperance Minerals N.L. released details of a report on the Alpha oil shale deposit near the town of Alpha in central Queensland. The deposit has 2.6 Mt of torbanite which, with an average grade of 420 litres/tonne, is capable of yielding 7.58 million barrels of oil. In addition there are 102 Mt of cannel coal with an average grade of 120 litres/tonne. Oil produced from the torbanite would yield 59% bitumens and 40% fuels. Retorted cannel coal could be used to generate sufficient electricity to meet the project's need with some surplus being available for input into the State grid. Studies of the possible use of Alpha torbanite spent shale to produce activated carbon showed that adsorbtion qualities similar to those of commercial activated carbon could be obtained. It was estimated that each tonne of torbanite could yield some 230 kg of activated carbon.

Information on world shale oil resources is incomplete. The World Energy Council's (WEC) 1995 Survey of Energy Resources provides some data on oil shale resources. WEC reports that, in 1993, Jordan, with 4000 Mt (oil), had the largest 'proved recoverable reserves' followed by Australia with 3651 Mt (oil) and the former USSR with 2000 Mt (oil). It does not report tonnages for the USA or China in this category. In the 'estimated additional reserves' category WEC reports the USA has by far the largest resource with 217 000 Mt (oil) followed by the former USSR (35 000 Mt (oil)) and Australia (32 374 Mt (oil)). The WEC estimates for Australia correspond well with the estimates reported by BRS in this publication in the demonstrated and inferred categories.

WEC notes that in 1993, production of shale oil occurred in Brazil (0.2 Mt (oil)), China (0.18 Mt (oil)) and the former USSR (0.15 Mt (oil)).

Tantalum

A small (1.3%) increase in EDR resulted mainly from the reclassification of resources to that category, more than offsetting loss to production. Subeconomic resources fell by almost 9% and inferred resources remained unchanged. All EDR are in Western Australia.

In Australia, Gwalia Consolidated Limited produced 531 548 pounds of Ta_2O_5 in 1995 from its Greenbushes mine in southwest Western Australia. Gwalia is the world's largest producer of tantalum products. Renison Goldfields Consolidated Ltd/Goldrim Mining Australia Ltd's Wodgina project, in the Pilbara region of Western Australia, was in production during the year. Prima Resources N.L produced 82 997 pounds of Ta_2O_5 from its Pilgangoora operation but noted that unless new resources were discovered the operation would be winding down by the end of 1995. In its report for the December 1995 quarter, Cove Mining N.L. said that mining and processing had begun at its Mount Farmer project in the Mount Magnet district of Western Australia.

Following several years of inactivity on its Bynoe property south of Darwin, Gwalia Consolidated undertook a new round of exploration during the year. It reported tantalum and tin mineralisation in six separate pegmatite bodies. A total resource of about 1 Mt with grades ranging from 130 to 320 ppm Ta_2O_5 was defined, although no resource classification was reported.

Australia is the world's second largest tantalum resource nation. Based on BRS data and estimates prepared by the USBM, Australia has about 28% of the world's economic resources. Thailand, with 33%, has the largest economic resource, followed by Australia, Nigeria (14.5%) and Canada and Zaire (8% each).

Just over half the world's tantalum output comes from Australia. Based on preliminary USBM statistics, the second largest producer in 1995 was Brazil with almost 15% followed by Canada with almost 9%. Although Thailand and Nigeria have substantial economic resources, their output accounted for less than 1% of world production.

Tin

Australia's demonstrated tin resources fell to 325 190 t in 1995, a decline of over 10% on the 1994 estimate. The fall resulted from reclassification, by the company RGC Ltd, of some low grade reserves at the Renison mine in Tasmania. EDR, which are dominated by the Renison deposit, fell by 14% to 136 170 t of tin.

At Renison the development of the Rendeep resource, which underlies current operations, has progressed and production, utilising the new ore shaft, should begin in the June quarter of 1996. The shaft will provide access to higher grade ores, increase production capacity, and should reduce haulage costs.

A significant tin resource occurs at the Greenbushes mine in Western Australia where it is produced as a by-product of

tantalite and spodumene mining. Greenbushes is also the sole site of tin smelting in Australia.

A major development was the commencement of mining in far north Queensland by Norminco Ltd at the company's Leichhardt Creek alluvial deposit during October 1995. Norminco hopes to develop resources at other deposits in the Mount Garnet district and surrounding areas, with the next most likely source of ore being the Tate River alluvial deposits. Ore produced from these deposits is to be concentrated at the Mount Veteran dressing plant, just outside the township of Mount Garnet. The company has reached an agreement to sell concentrates for the next two years to a Malaysian smelting company.

Australia has about 2% of world EDR. China, Indonesia and Brazil dominate both world resources and production of tin. Australia produces about 4% of world tin output and is ranked 8th.

Uranium

BRS has prepared estimates of Australia's uranium (U) resources according to categories defined by the OECD Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA) (OECD/NEA & IAEA 1996). The estimates were calculated using drilling data provided by mining companies. In Table 1, these estimates are reported under the corresponding resource categories of the BRS classification scheme. Comparisons of the resource categories within both these schemes are shown below.

BRS scheme	OECD/NEA & IAEA scheme
Economic Demonstrated Resources	Reasonably Assured Resources (RAR) recoverable at less than US$80/ kg U (commonly referred to as low cost resources)
Subeconomic Demonstrated Resources	RAR recoverable at US$80–130/ kg U
Economic Inferred Resources	Estimated Additional Resources Category 1 (EAR-1) recoverable at less than US$80/ kg U
Subeconomic Inferred Resources	EAR-1 recoverable at US$80–130/ kg U

Australia has the world's largest resources of uranium in the low cost RAR category, with 30% of world resources in this category. Other countries which have large low-cost resources include Kazakstan (21%), Canada (13%), South Africa (10%), Namibia (8%), Brazil (8%) and United States (5%).

Since the break-up of the former USSR in 1991, Kazakstan, Ukraine, Russian Federation and Uzbekistan have reported large resources of low-cost uranium. Kazakstan and Ukraine together have approximately 23% of the world's low-cost resources. Estimates of resources for the Russian Federation and Uzbekistan are not reported within the standard OECD/NEA categories, and consequently it is difficult to compare these estimates with those for other countries.

In Australia, uranium is currently produced at two mining/milling operations, namely Ranger (Northern Territory) and Olympic Dam (South Australia). Mining at the Ranger No. 1 open pit was completed in December 1994 and Energy Resources of Australia Ltd (ERA) reported that stockpiled ore is sufficient to maintain milling operations through to 1999. ERA has two undeveloped uranium deposits: Ranger Orebody No. 3 which lies adjacent to the Ranger mill, and Jabiluka located 20 km north of the mill on an adjoining lease. ERA plans to commence production in 1997 from Ranger Orebody No. 3 which has proven plus probable reserves of 56 000 t contained uranium oxide U_3O_8 (47 500 t U) in ore grading 0.31% U_3O_8 (0.26%U).

The Olympic Dam deposit is mined for copper, uranium, gold and silver. It is the world's largest deposit of low-cost uranium. Western Mining Corporation Ltd is investigating a proposal for a major expansion at the Olympic Dam operations which will increase production capacity from the present levels of around 1400 t U_3O_8 a year to approximately 3700 t U_3O_8 a year.

The Liberal-National Party Coalition, elected to government in March 1996, has abolished the 'three mines' uranium policy introduced by the previous government. Any proposals for new uranium mines and exports of uranium will be approved if they comply with environmental, heritage and nuclear safeguards requirements.

A number of uranium deposits which could not be developed under the 'three mines' policy are now likely to be proposed as new mining operations in the future. These include Jabiluka (Northern Territory), Kintyre (Western Australia), Koongarra (Northern Territory), Yeelirrie (Western Australia), Westmoreland (Queensland) and Beverley (South Australia).

Since 1990, ownership of many of Australia's major uranium deposits has changed through acquisitions, company mergers and withdrawal of small companies from joint venture arrangements. There has been a tendency for companies to increase ownership of resources by direct acquisition. As a consequence, there has been an overall consolidation in ownership of Australia's uranium resources, most of which are now held by a few large mining

companies - ERA Ltd (Ranger, Jabiluka), Western Mining Corporation Ltd (Olympic Dam, Yeelirrie), CRA Ltd (Kintyre, Westmoreland), Cogema Australia Pty Ltd (Koongarra, Ben Lomond, Manyingee), PNC Exploration Pty Ltd (Mulga Rock) and Heathgate Pty Ltd (Beverley).

Australia's total production of 2208 t U for 1994 represented 7% of world production. Australia ranked as the fifth largest producing country after Canada, Niger, Russian Federation and Kazakstan.

Zinc, lead, silver

The 1995 EDR estimates for zinc (38.8 Mt), lead (18.2 Mt) and silver (41.5 Kt) represent a decrease ranging from 7–10% for these metals since 1994. However, Australia's stocks of identified resources of zinc increased by 5.5 Mt (6%), lead by 2.8 Mt (5%) and silver by 4.2 kt (5%). This consolidates the large gains of 1993 contributed by the Cannington and Century deposits in Queensland, and the upgrade of the McArthur River deposit in the Northern Territory.

Much of the 3.8 Mt decrease in zinc EDR and 1.5 Mt decrease in lead EDR resulted from the transfer of the old Hilton North resources (now reported as the George Fisher deposit), in Queensland, to inferred resources. Mt Isa in Queensland, and Hellyer and Rosebery in Tasmania, recorded small decreases because of production. At Broken Hill, New South Wales, production and resource re-modelling resulted in an overall small decrease in EDR and the total remaining resource; however, infill drilling and detailed pit design generated a small increase in the open pit Potosi resource, where mine life is expected to be four years at a mining rate of 250–300 000 t a year of ore. The decreases were further offset by substantial rises in EDR and identified resources at Elura (New South Wales) and Blendevale (Western Australia).

The first concentrate was shipped from the large zinc–lead–silver McArthur River deposit to Europe in August 1995, some 40 years after discovery of the deposit. Mine development was hindered over that period by a lack of infrastructure and in particular the difficulty of processing the very fine grained ore. ISAMILL fine grinding technology, developed by Mount Isa Mines Limited to liberate fine grained ore minerals, was a key factor in enabling mining to proceed.

Production and reappraisal at Mt Isa resulted in a substantial decrease in Proved Reserves to 17.6 Mt of lead–zinc ore, down from 33 Mt last year. Some reserve was transferred to other resource categories and some was removed from the resources statement.

Silver EDR decreased by 5.4 Kt due to decreases at the major Queensland and Tasmanian deposits. Small increases were recorded at Kidston (Queensland) and Mt Lyell (Tasmania). At Kidston, small oxide ore reserves at Macks and North Knob were mined out in 1995 and the main Wises Hill open pit is expected to finish by mid 1996. However, the adjacent, new Eldridge resource will sustain the Kidston operation into the next century. A number of exploration targets have been identified in the Kidston breccia complex around the mine area.

Table 2 Australian production and exports of selected mineral products 1994–95.

Commodity	Production	Exports	Export value $ million
Aluminium			
Bauxite (Mt)	42.4	na	88
Alumina (Mt)	12.94	10.32	2231
Aluminium (Mt)	1.28	0.92	2171
Coal			
Black raw (Mt)	237.2	—	—
Black saleable (Mt)	192.3	136.2	6874
Brown (Mt)	48.3	—	—
Copper			
Ores and concentrates (kt)	350	426	377
Refined primary (kt)	281	121	420
Diamond (kc)	43674	34707	572
Gold			
Mine production (t)	248.6		
Refined (t)[(a)]	286.9	284	4690
Iron and steel			
Ore and pellets (Mt)	136.8	128.7	2772
Iron and steel (Mt)[(b)]	15.8	2.86	1378
Lead			
Ores and concentrates (kt)	455	168	60
Refined (kt)	207	188	181
Bullion (kt)	178	168	170
Nickel			
Mine production (kt)	97		
Refined (kt)	73[(c)]	na	950
Manganese ores and concentrates (Mt)	2.047	1.576	202
Mineral sands			
Ilmenite concentrates (kt)	1648	1014	87
Rutile concentrates (kt)	235	213	121
Synthetic rutile (kt)	489	300	145
Titanium dioxide pigment (kt)	165	122	293
Zircon concentrates (kt)	523	524	155
Uranium (t U_3O_8)	2632	4069	188
Zinc			
Mine production (kt)	917	1286	404
Refined (kt)	313	238	372

na = not available; t = tonnes; kt = 10^3 t; Mt = 10^6 t; kc = 10^3 carats

Sources: *Australian Commodities Forecasts and Issues* ABARE December quarter 1995
Australian Commodity Statistics, ABARE December 1995

(a) Includes gold of Australian and overseas origin

(b) Includes 7.4 Mt pig iron and 8.4 Mt raw steel

(c) Sum of products in the <99% Ni and >99% Ni categories

Silver EDR decreased at Elura in contrast to increased zinc–lead EDR referred to above. At Broken Hill, demonstrated resources decreased through mine production while resource re-modelling resulted in some mineralisation being deleted from the resource inventory.

Australia has the world's largest EDR of zinc (28%), lead (29%) and silver (15%). As a producer, Australia ranks first in the world for lead and zinc and fourth for silver. Production is mainly from mines at Mount Isa, McArthur River, Broken Hill, Elura, Hellyer and Rosebery. Gold mines are significant contributors to silver production.

Mineral industry performance

Statistics published by ABARE (1995) show that mineral exports for 1994–95 were valued at $30 267 million, an increase of $484 million over the 1993–94 figure. ABARE forecast that for the 1995–96 year export earnings will rise to $34 586 million. Mineral exports accounted for just over 60% of all commodity exports by value. Details of production and exports of selected minerals are reported in Table 2.

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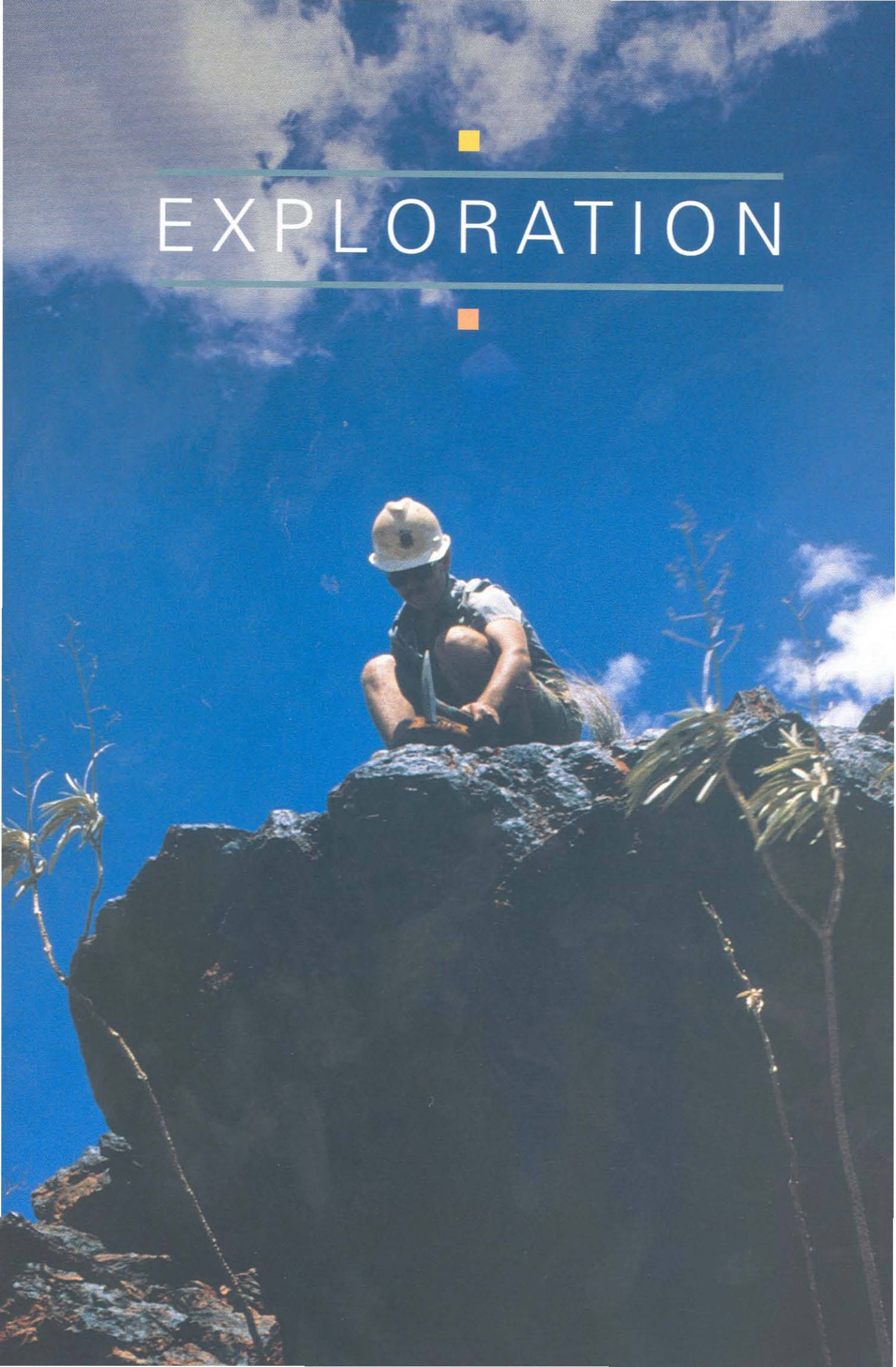
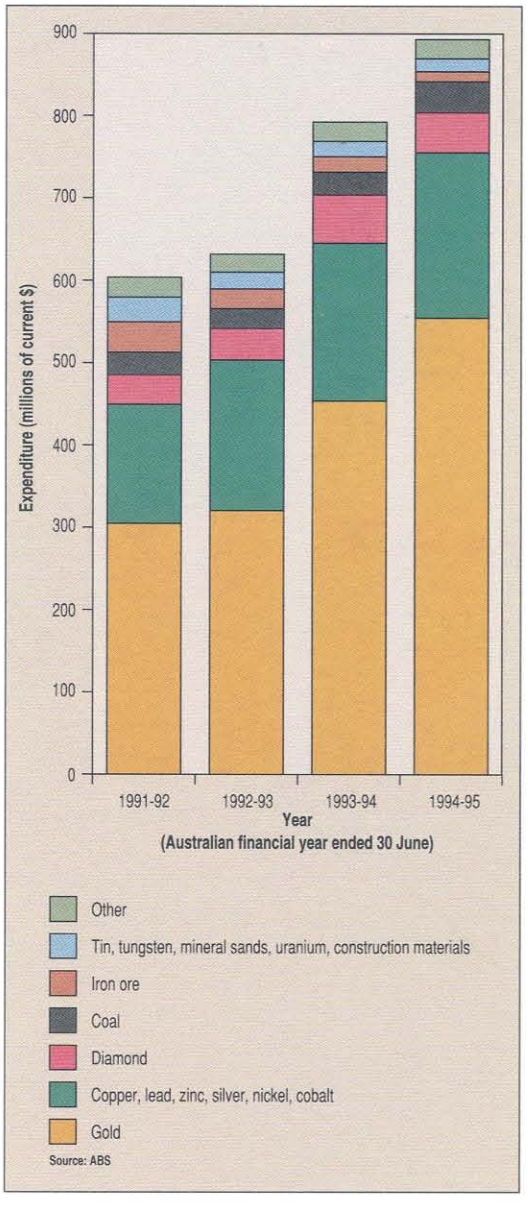
EXPLORATION



Exploration expenditure

Mineral exploration expenditure for a range of commodity groups is monitored regularly by the Australian Bureau of Statistics (ABS) and the following discussion and statistics are based on the 1994–95 survey data. The differentiation of commodity groups before 1980 is based largely on a breakdown of ABS totals by BRS.

Figure 2 Annual exploration expenditure since 1990–91



Mineral exploration expenditure in Australia during 1994–95 rose by about $100 million dollars or 13% from a total of $793 million in 1993–94 to a peak of $893.3 million (Figure 2). Most of the increase is attributable to a continued strong emphasis on gold exploration which rose from $454 million to $555 million. Most of the increase in gold exploration expenditure took place in Western Australia and Queensland.

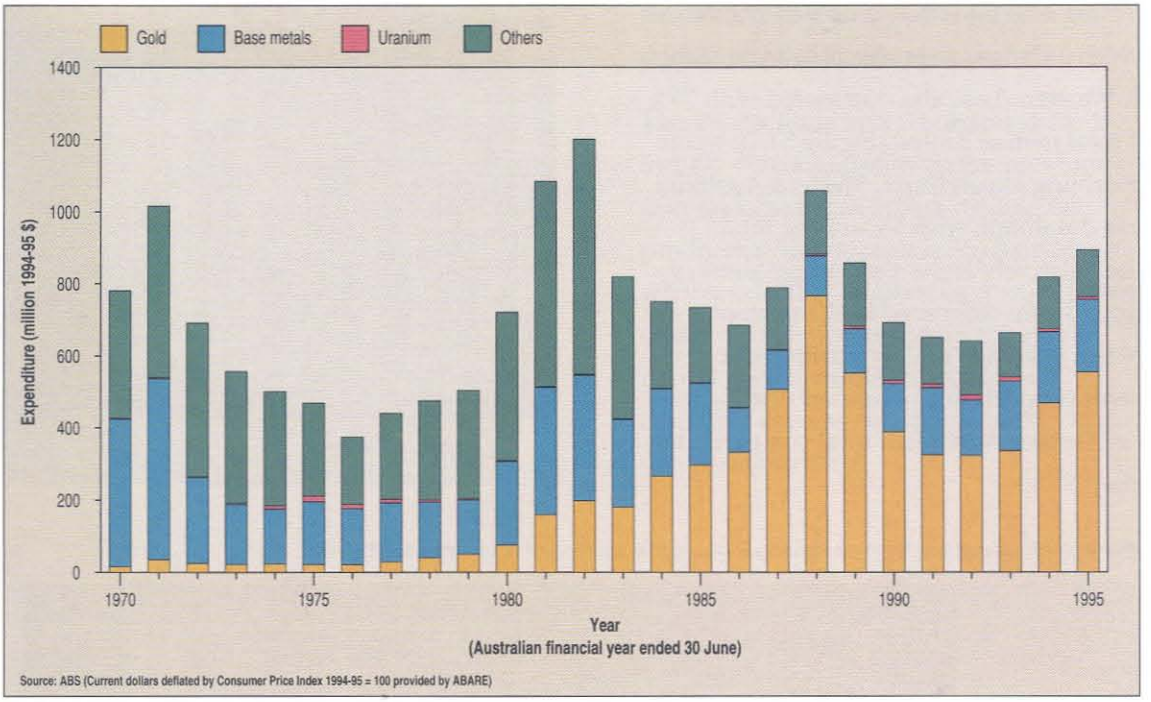
All States showed increases in total exploration expenditure except for South Australia which was marginally lower. Overall, Western Australia was responsible for 55% of exploration expenditure followed by Queensland with 20% and the Northern Territory with 8%.

Gold accounted for 62% of total Australian exploration expenditure by commodity group followed by a group made up of the base metals (copper–lead–zinc) plus silver, nickel, and cobalt with 23% and diamonds with 5%.

Apart from the strong rise in gold exploration, expenditure on base metals and coal exploration also increased, while spending on iron ore and mineral sands fell by about 30%. Although diamond exploration maintained a significant share of total exploration expenditure it fell by almost 20% in 1994–95.

Expenditure on "greenfields" exploration rose faster than the recent 5 year average whereas the rate of increase in exploration expenditure on "production-leases" slowed. Overall, about 23% or $202 million was spent on "production leases" in 1994–95 while 77% or $691 million was spent on "greenfields" leases.

Figure 3 Australian exploration expenditure since 1969–70 expressed in 1994–95 dollars



In constant (1994–95 dollars) dollar terms, the rise in exploration expenditure which began in 1992–93 continued through 1994 and 1995 (Figure 3), but the level of expenditure has not yet reached the peak attained in 1987–88 nor the all time high reached in 1981–82.

Exploration drilling

In 1995, BRS again commissioned ABS to undertake a survey of exploration and mining companies to ascertain the amount and type of exploration drilling carried out in Australia in 1994–95. This study was undertaken on behalf of the Conference of Chief Government Geologists to enable a State-by-State analysis of expenditure and metres drilled by type of drilling to be made. A summary of the reported data was released by ABS on 24 January 1996 (ABS Catalogue No. 8412.0).

Of the $893.3 million expended on exploration in 1994–95, $322.2 million, or 36%, was spent on drilling.

A State-by-State breakdown of drilling expenditure is incorporated into Table 3. About 41% of exploration expenditure in Western Australia was directed to drilling in 1994–95 (Figure 4), compared to about 15% for South Australia.

Table 3 Exploration expenditure and exploration drilling, 1994-95

State	Total exploration expenditure ($ million)	Exploration drilling	
		$ million[(a)]	'000 metres[(a)]
New South Wales	79.2	24.805	505
Victoria	31.2	5.731	119
Queensland	176.0	60.875	1151
South Australia	20.9	3.159	65
Western Australia	495.5	203.708	7256
Tasmania	14.9	4.580	58
Northern Territory	75.8	19.161	557
Australia	893.3	322.019	9711

Note: Totals and sums of components may vary because of rounding.

(a) Statistics collected by Australian Bureau of Statistics for Bureau of Resource Sciences, on behalf of the Conference of Chief Government Geologists.

About 9.7 million metres of exploration drilling was undertaken in 1994–95, of which 34% was in production areas (Table 4). Western Australia dominated with 75% of total metres drilled (Figure 5). In terms of drilling expenditure, Western Australia was dominant, with 55% of the total. This relatively lower percentage share of expenditure compared to the percentage of metres drilled is mainly attributed to the lower proportion of diamond drilling in the Western Australian total compared to other States.

Figure 4 Proportion of Australia exploration expenditure spent on drilling in each State during1994–95

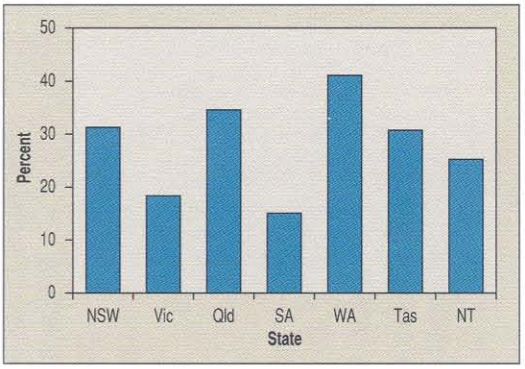


Table 4 Methods of exploration drilling in Australia by type of area drilled, 1994–95.

	Production areas			Other areas			Total		
	'000 metres[(a)]	'000 $[(a)]	Average $/m	'000 metres[(a)]	'000 $[(a)]	Average $/m	'000 metres[(a)]	'000 $[(a)]	Average $/m
Diamond	766.4	78627	102.59	636.0	73151	115.02	1402.4	151778	108.23
Reverse circulation	1597.7	47641	29.82	2248.2	66968	29.79	3845.9	114609	29.80
Percussion	90.5	2863	31.64	222.9	7154	32.10	313.4	10017	31.96
Rotary air blast	752.5	8353	11.10	2784.8	28686	10.30	3537.3	37039	10.47
Others	94.1	1776	18.87	517.5	6800	13.14	611.6	8576	14.02
Total	3301.2	139260	42.18	6409.4	182759	28.51	9710.6	322019	33.16

(a) Statistics collected by Australian Bureau of Statistics for Bureau of Resource Sciences, on behalf of the Conference of Chief Government Geologists

Exploration drilling outside of production areas (66% of all exploration metres drilled) totalled 6.409 million metres at a cost of $182.8 million. Table 4 and Figure 6 summarise exploration drilling statistics for 1994–95.

Overall expenditure on drilling increased by 14% to $322 million in 1994–95. Despite this, actual metres drilled decreased by 4% to 9.711 million metres compared with 10.082 million metres in the previous year. RAB drilling costs in all areas escalated by 16% overall, while RAB costs in production lease areas rose by as much as 32%. Reverse circulation drilling costs in all areas escalated by 12% while diamond

Figure 5 Australian exploration metres drilled in each State during 1993–94 and 1994–95

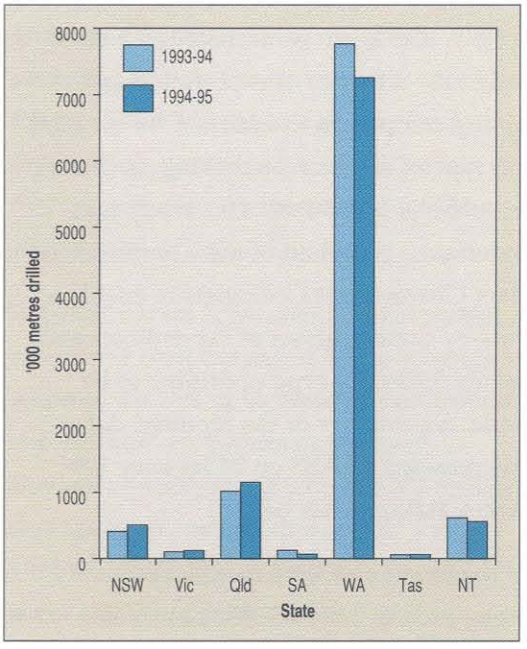
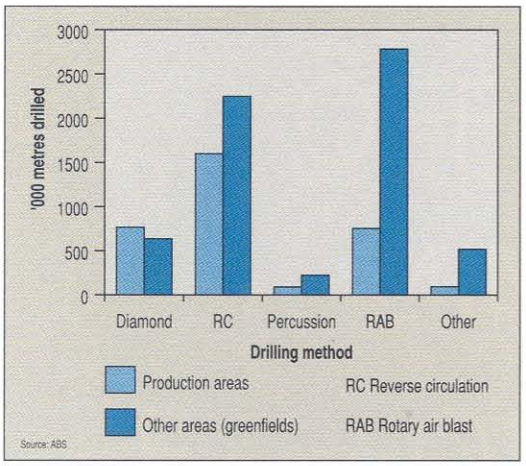


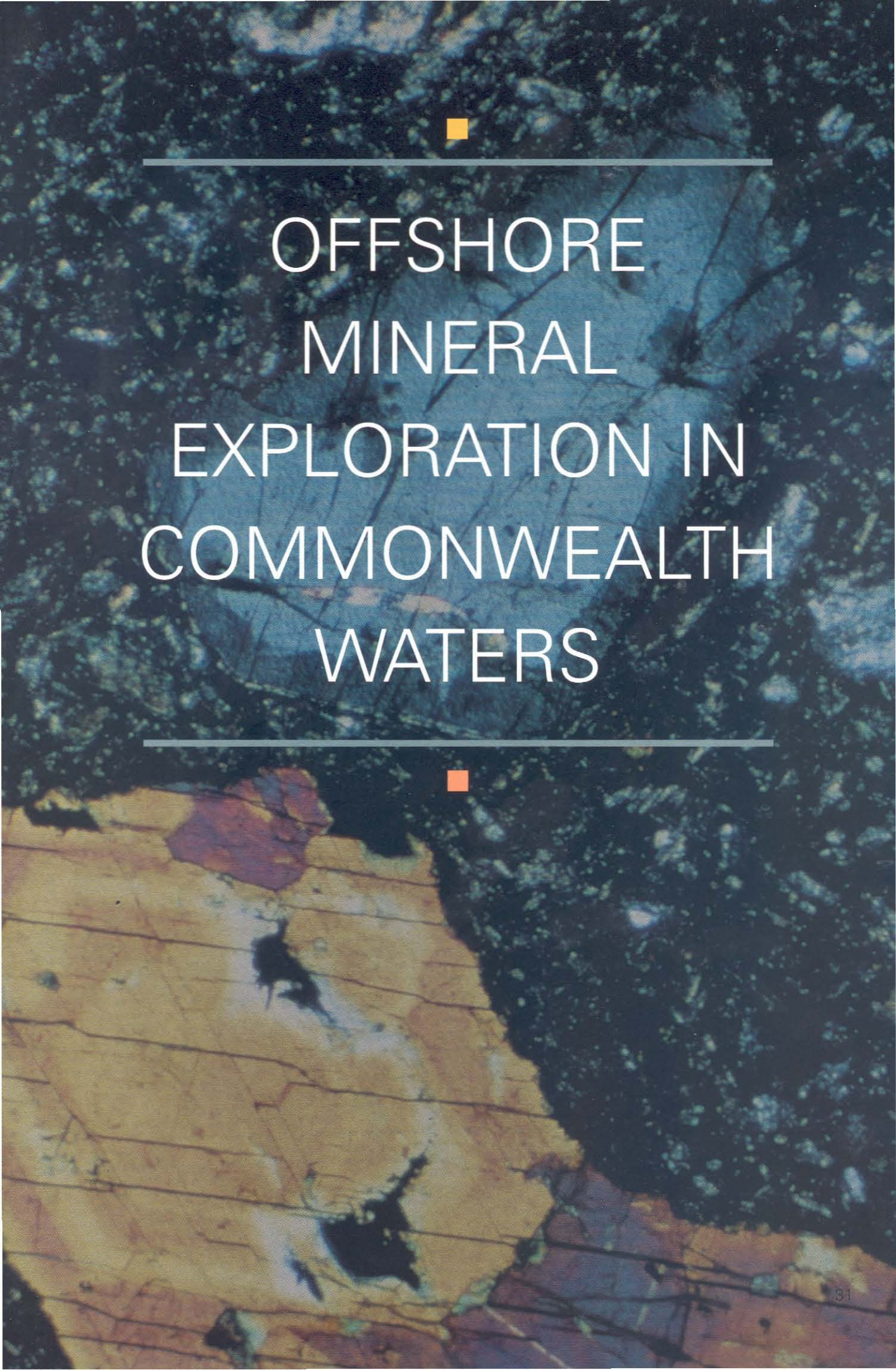
Figure 6 Exploration drilling, by drilling method and by area, 1994–95



drilling costs went up by 8%. However, percussion and other drilling costs decreased slightly over the period.

The 4% decrease in total metres drilled in 1994–95 compared with the previous year was the result of less drilling on production leases, mainly RAB drilling, whereas drilling in greenfield areas (other areas) actually increased by 2% in the period with increases recorded in diamond, reverse circulation and percussion drilling.

OFFSHORE MINERAL EXPLORATION IN COMMONWEALTH WATERS



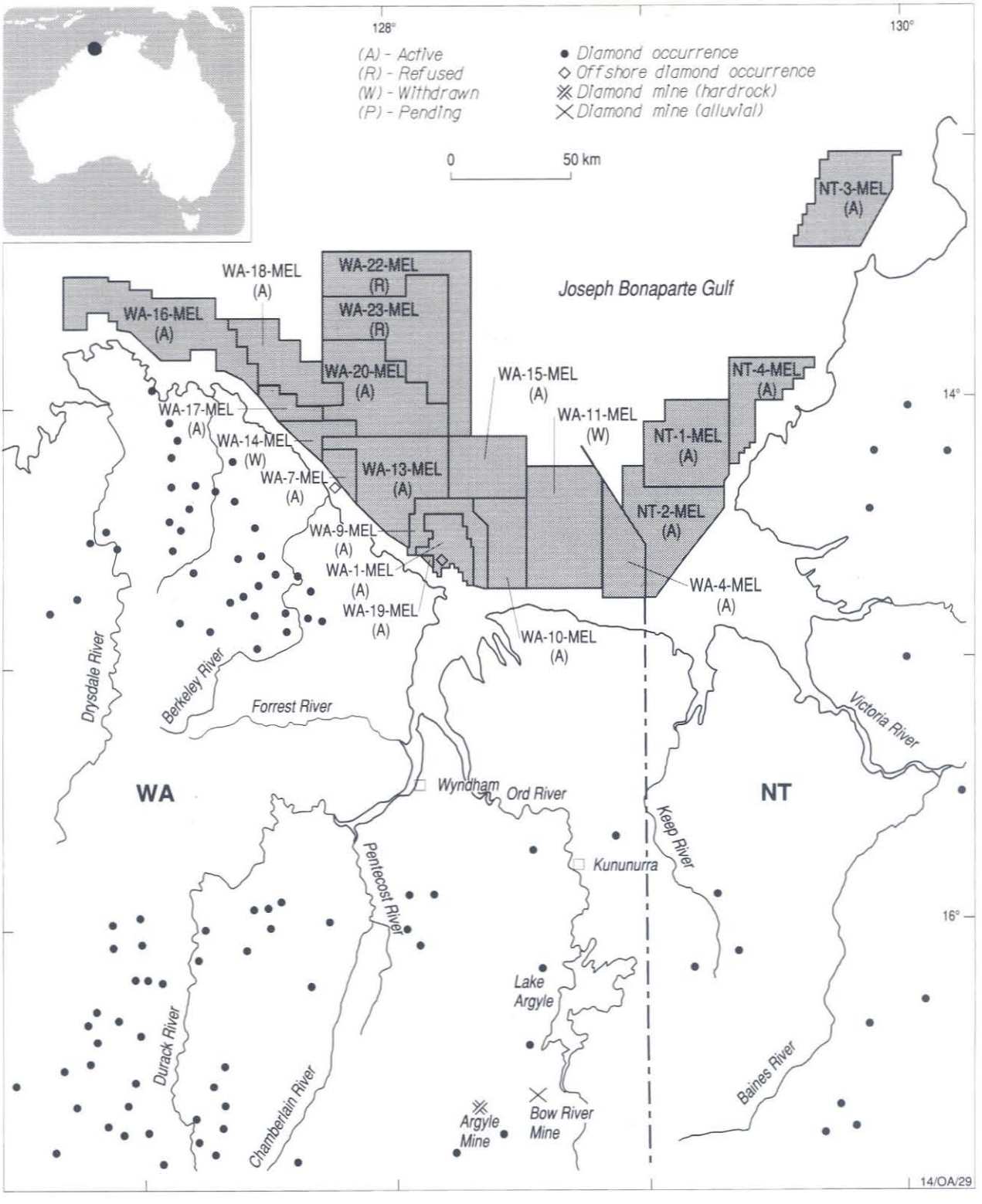
Australia's *Offshore Minerals Act 1994* regulates exploration for minerals and mining of minerals, other than petroleum, over the continental shelf three nautical miles beyond the territorial baseline of the States and Territories.

As at 12 March 1996, a total of 47 offshore mineral exploration licences (MEL) applications had been received. There are 17 active MELs (13 offshore Western Australia and 4 offshore Northern Territory). Sixteen of the active licences are in the Joseph Bonaparte Gulf (Figure 7). Since 1990, there has been significant exploration activity in the Gulf, based on conceptual geological modelling that suggests that marine alluvial diamonds might be found in mineable quantities. The modelling postulates that alluvial diamonds may be derived from the erosion of onshore diamond deposits as exemplified by the Argyle pipe.

To the end of 1995, approximately 2700 line kilometres of reconnaissance and detailed seismic surveys had been undertaken in Commonwealth waters in the Gulf. These surveys were aimed at locating palaeo-drainage channels and other geological features that may host potentially diamondiferous sediments. Interpretation of the seismic data facilitated the selection of drilling targets. To date, only Cambridge Gulf Exploration N.L. has undertaken exploration drilling in Commonwealth waters. In November 1993 this company found 23 gem quality macrodiamonds totalling 5.87 carats (c) using airlift drilling techniques within WA-1-MEL. In 1994, 14 gem quality macrodiamonds totalling 8.80 c were found offshore from the Berkeley River in Western Australian waters (EL80/1563).

By the end of 1995, approximately $10 million had been spent on exploration in Commonwealth waters in the Gulf. This expenditure has proven the existence of gem quality macrodiamonds in the area and more resources are now being provided to determine if commercial deposits of marine alluvial diamonds exist.

Figure 7 Commonwealth Offshore Mineral Exploration Licences in the Joseph Bonaparte Gulf as at 12 March 1996.



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