Australia's Identified *Mineral Resources*

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2000

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Department of Industry, Science & Resources

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Front cover photo: umbilical discharge of alumina into ship's hold, Alcoa's Kwinana refinery, Western Australia (courtesy Alcoa of Australia Ltd).

Back cover photo: alumina ship loading facility, Alcoa's Kwinana refinery, Western Australia (courtesy Alcoa of Australia Ltd).

Foreword

As Australia's national geoscientific research and information agency, the Australian Geological Survey Organisation (AGSO), provides the Commonwealth Government with information on the nation's future capacity to produce mineral resources. Australia's Identified Mineral Resources (AIMR) is an AGSO output that provides an annual nation-wide assessment of the ore reserves and mineral resources base for all major and a number of minor mineral commodities mined in Australia. It also includes international rankings, summaries of significant exploration results, brief reviews of mining industry developments, and an analysis of mineral exploration expenditure across the States and Northern Territory.

As a package, AIMR provides governments, industry, the investment sector and general community with an informed understanding of Australia's known mineral endowment and level of exploration activity. National assessments of this type are also assuming greater global significance, as issues concerning cost-effective cleaner mining and product stewardship receive closer attention.

AGSO underpins Government resource policy and management decisions by appraising the mineral resource potential of areas being considered for restricted land use; advising on environmental issues in relation to exploration, mining, rehabilitation, and mineral processing; and providing advice on offshore exploration and mining issues. In 2000–01, it will be allocating resources to achieve increased integration of geoscience information in risk management and decision support, particularly in regard to land management in areas effected by salinity.

This is likely to be the last hardcopy edition of AIMR. As part of the Commonwealth Government's commitment to putting all appropriate Government services online by 2001, the next edition (AIMR 2001) will probably be an electronic publication available through AGSO's website.

Neil Williams

Chief Executive Officer

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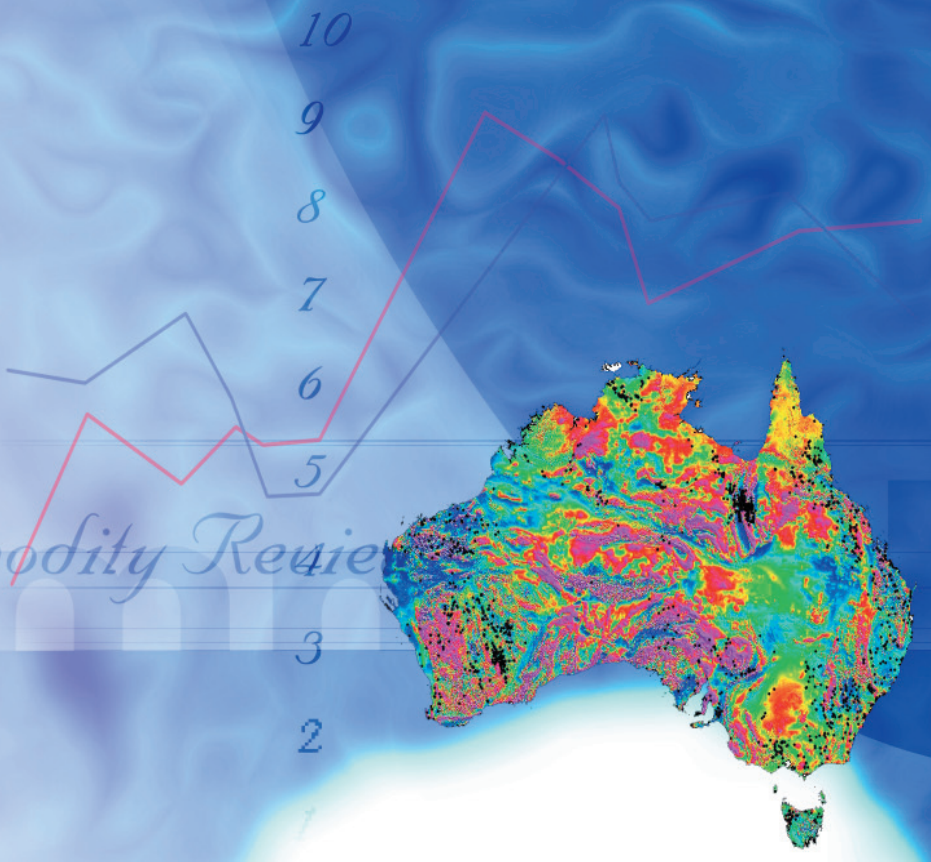


Summary

In 1999, Australia's economic demonstrated resources (EDR) of bauxite, diamond, gold, iron ore, manganese ore, magnesite, mineral sands (ilmenite, rutile, and zircon), nickel, phosphate rock and tantalum rose, while those of copper, coal (black and brown), lead, lithium, silver, uranium and zinc fell. The reductions in EDR were due mainly to ongoing high levels of production; commodity prices were a subsidiary factor. EDR of all other commodities remained effectively unchanged.

EDR of bauxite and manganese ore increased by 16% and over 22% respectively, following reviews of resources information that became available during the year. Increases in EDR of both gem/near gem and industrial diamond resulted from delineation of additional resources in Western Australia. EDR of nickel and tantalum again reached record levels. Gold increased by 14%, surpassing the previous EDR high established in 1996.

Australia continues to rank highly as one of the world's leading mineral resource nations. It has the world's largest EDR of lead, mineral sands, nickel, silver, tantalum, uranium and zinc. In addition, its EDR is in the top six worldwide for bauxite, black coal, brown coal, copper, cobalt, copper, gold, iron ore, lithium, manganese ore, rare earth oxides, gem/near gem diamond and vanadium.

Mineral exploration expenditure fell by 21.5% from $1066.8 million in 1997–98 to $837.8 million in 1998–99. The largest reductions were recorded in Tasmania (43%), Queensland (30%), Western Australia (21%), Northern Territory (15%) and Victoria (14%). Gold recorded a substantive fall of 25%, but remained the principal focus of mineral exploration with 58% of total expenditure. Of the total mineral exploration expenditure, 76% or $638.7 million was spent in greenfields areas and $199.1 million in brownfields areas. A variable response in exploration spending is expected to reflect changes in commodity prices.

Production of many mineral commodities reached record levels in 1998–99, and overall mine production is projected by ABARE to rise by around 6% in the five years to 2004–05. Substantial growth in mine output over this period is expected for nickel (65%), copper-zinc-lead (4-15%), alumina (13%) and iron ore (16%). Costs of production continue to be reduced as exploration, mining and processing technologies improve and production processes become more efficient.

Introduction

This report presents the second annual assessment of Australia's identified mineral resources by the Australian Geological Survey Organisation (AGSO). It continues a series of national mineral resource assessments that have been published by the Australian Government since 1975.

The assessment is undertaken as input into Government policy decisions relating to the sustainable development of mineral resources. 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 1998-99 and the previous five fiscal years. The current level of expenditure is put into perspective by comparing it in real terms to expenditure over the preceding 29 years.

Estimates of Australia's identified resources of all major and several minor mineral commodities are reported for 1999 (Table 1). The estimates are based on published and unpublished data available to AGSO up to the end of December 1999.

Data on petroleum resources were provided by AGSO's Petroleum Engineering and Identified Resources Project. World data have been obtained or calculated from data in various sources, but mainly in publications of the United States Geological Survey (USGS).

The mineral resource classification used in this report reflects both the geological certainty of existence of the mineral resource and the economic feasibility of its extraction (see 'National classification system for identified mineral resources' at the end of this report). The classification category, economic demonstrated resources (EDR), is used instead of 'reserves' for national totals of economic resources because the term 'reserve' has specific meanings for individual mineral deposits under the criteria of the Joint Ore Reserves Committee (JORC) code used by industry for reporting reserves and resources. EDR also provide 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 therefore depleted by mining and increased by new discoveries, and by technical and economic changes that can allow formerly subeconomic deposits to be reclassified as economic.

AGSO 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 1999). In this publication these estimates are reported under the corresponding resource categories of the national classification scheme. A correlation of the national 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 generally 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 and to the highly prospective nature of the continent.

Table 1. Australia's resources of major minerals and fuels, and world figures for 1999.

Commodity	Units	Australia							World	
		Demonstrated			Inferred			Mine Production (f)	Economic demonstrated resource (l)	Mine Production (a)
		Economic	Sub-economic		Economic	Sub-economic	Undifferentiated			
			Para-marginal	Sub-marginal						
Antimony	kt Sb	78.5	21.6	49.8	19	35.8	21.1	2.3	2,100	138
Asbestos										
Chrysotile ore	Mt	-	46.24	-	-	-	75.18	-	large	
Crocidolite fibre	Mt	-	0.37	-	-	-	2.12	-	large	1.79 (k)
Bauxite	Mt	3,764	3,640	1,729	-	-	1,038	48.4	25,000	123 (b)
Black coal										
in situ	Gt	64.9	1.5	13.9	-	-	very large			
recoverable	Gt	44.4	1.1	9.2	-	-	very large	0.294 (c)	774 (o)	3.7 (d) (o)
Brown coal										
in situ	Gt	41.9	43.4	18.3	-	-	113.6			
recoverable	Gt	37.7	39.0	16.4	-	-	102.2	0.067	190(o)	0.8(o)
Cadmium	kt Cd	108.8	8.9	24.7	23	1.3	-	na	600	19.9
Cobalt	kt Co	878	90.1	308.1	-	-	1,208.3	1.1	4,698	28.3
Copper (p)	Mt Cu	22.2	17.3	1.1	1.1	3.2	12.3	0.73	355	12.6
Diamond										
gem & near gem	Mc	82.4	196	0.1	1.4	21.4	1.1	30.8	-	56.2
industrial	Mc	85.5	202.4	0.3	0.1	36.7	0.4		580	60.5
Fluorine	Mt F	-	24.34	9.36	-	-	2.99	-	107 (i)	2.06
Gold	t Au	5,018	1,003	125	-	-	2,568	302.5	50,018	2,330
Iron ore	Gt	15.5	4.6	1.4	-	-	16.1	0.155	140.0	0.99
Lead	Mt Pb	14.6	3.5	10.2	6.6	15.4	0.7	0.68	64	3.04
Lithium	kt Li	156	79	3	-	-	7	na	3,400	15 (b)
Magnesite	Mt $MgCO_3$	245.9	221	358.3	-	-	735.8	0.28	8,806	10.5 (b)
Manganese ore	Mt	134.3	23.1	167.0	-	-	164.4	1.9	1893	20.1
Mineral sands										
Ilmenite	Mt	180.9	65.8	0.2	-	-	112.3	1.9	654	6.32 (b)
Rutile	Mt	19.8	36	0.3	-	-	33.6	0.19	47.15	0.38 (b)
Zircon	Mt	26.3	26.9	0.4	-	-	27.9	0.38	67.7	0.79 (b)
Molybdenum	kt Mo	-	6.3	3.2	-	-	854	-	5,500	129
Nickel	Mt Ni	10.6	3.1	4.5	-	-	16.1	0.13	47.5	1.14
Niobium	kt Nb	16.1	67.6	-	-	-	1,994	-	3,500	18.5
Petroleum (recoverable)(e)										
Crude oil	GL	266	-	15	-	-	-	22.6		
Natural (sales) gas	10^9m^3	1,494	-	1,285	-	-	-	30.7		
Condensate	GL	192	-	87	-	-	-	7.5		
LPG naturally occur.	GL	184	-	129	-	-	-	4.1		
Phosphate rock	Mt	107	981	-	-	-	3,739		12,000	138
PGM (Pt,Pd,Os,Ir,Ru,Rh)(q)	t metal	36.1	13.3	28.4	3.5	94.6	3.9	na	71,000	150 (j)
Rare earths										
REO & Y_2O_3	Mt	0.83	3.5	9.9	-	-	15.5	-	100	0.08
Shale oil (q)	GL	-	461	3,345	-	-	41,425	-	na	na
Silver	kt Ag	31.2	10.5	12.6	15.6	13.4	2.1	1.7	280	15.9
Tantalum	kt Ta	24.7	20.0	0.17	-	-	62.8	0.41	29.7	0.48
Tin (q)	kt Sn	100.9	19.1	182.2	-	298.0	73.4	10	7,700	210
Tungsten (q)	kt W	0.98	34.22	27.99	2.47	177.61	-	-	2,000	31.3
Uranium (g)	kt U	571	-	99	177	59	-	7.055 (n)	2,238 (h)	31.1 (m)
Vanadium	kt V	180	1,736	594	700	3,419	-	-	10,000	40.0 (b)
Zinc	Mt Zn	32	10.4	17.7	10.3	10.5	0.7	1.06	190	7.6

Abbreviations: t = tonne; m^3 = cubic metre; L = litre; kt = 10^3t; Mc = 10^6 carat; Mt = 10^6t; Gt = 10^9t; GL = 10^9L; na = not available.

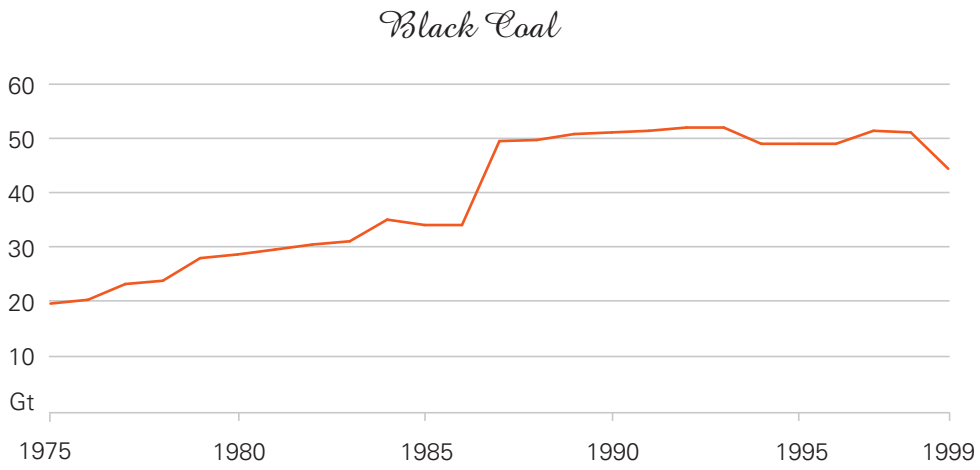
(a) World mine production for 1999, mostly USGS estimates

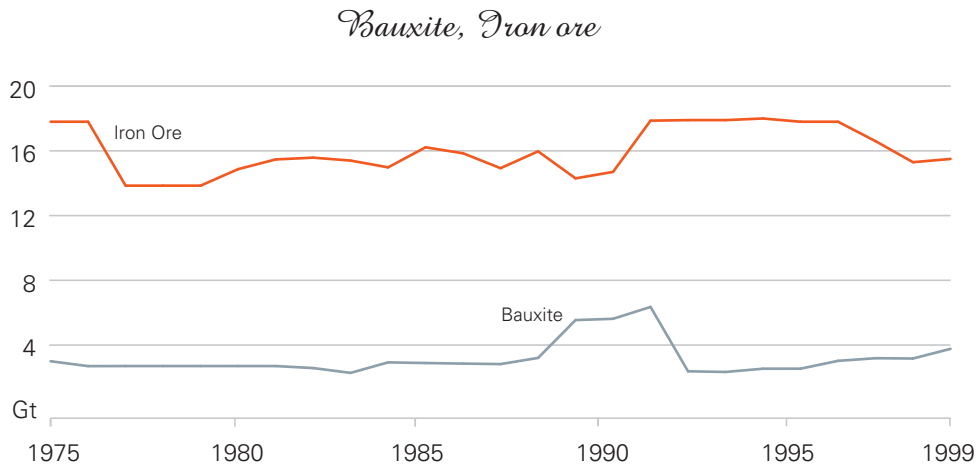
(b) Excludes USA
(c) Raw coal
(d) Saleable coal
(e) Source: Petroleum Resources Branch, AGSO (as at 31 December 1997)
(f) Source: ABARE.
(g) Refer to text for comparison of resource categories in the national scheme with those of the international scheme for classifying uranium resources

(h) Compiled from most recent resources data published by OECD/NEA and IAEA

(i) Excludes Morocco and Brazil
(j) Platinum only
(k) Includes crocidolite production
(l) Based on AGSO, USGS and other sources
(m) Source: Ux Weekly, 20 March 2000
(n) U_3O_8 (source: AGSO, U = 0.848 x U_3O_8)
(o) AGSO estimate
(p) Provisional assessment
(q) Not assessed for 1999

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





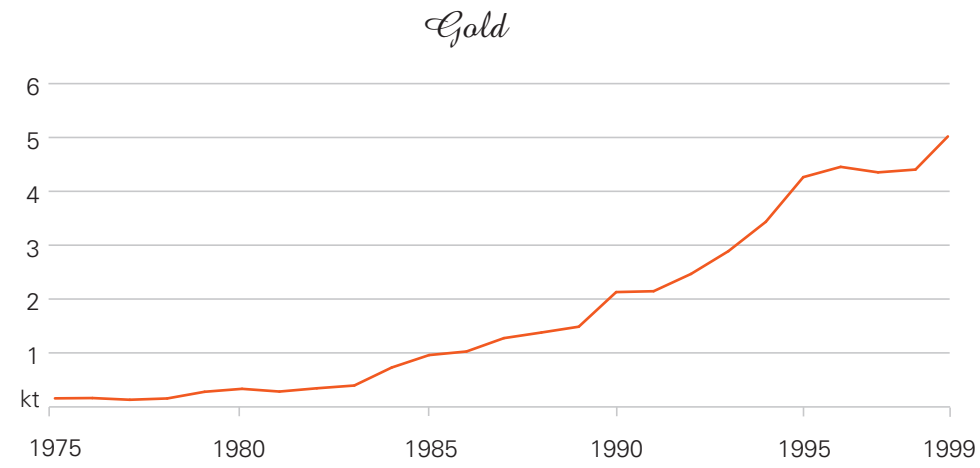
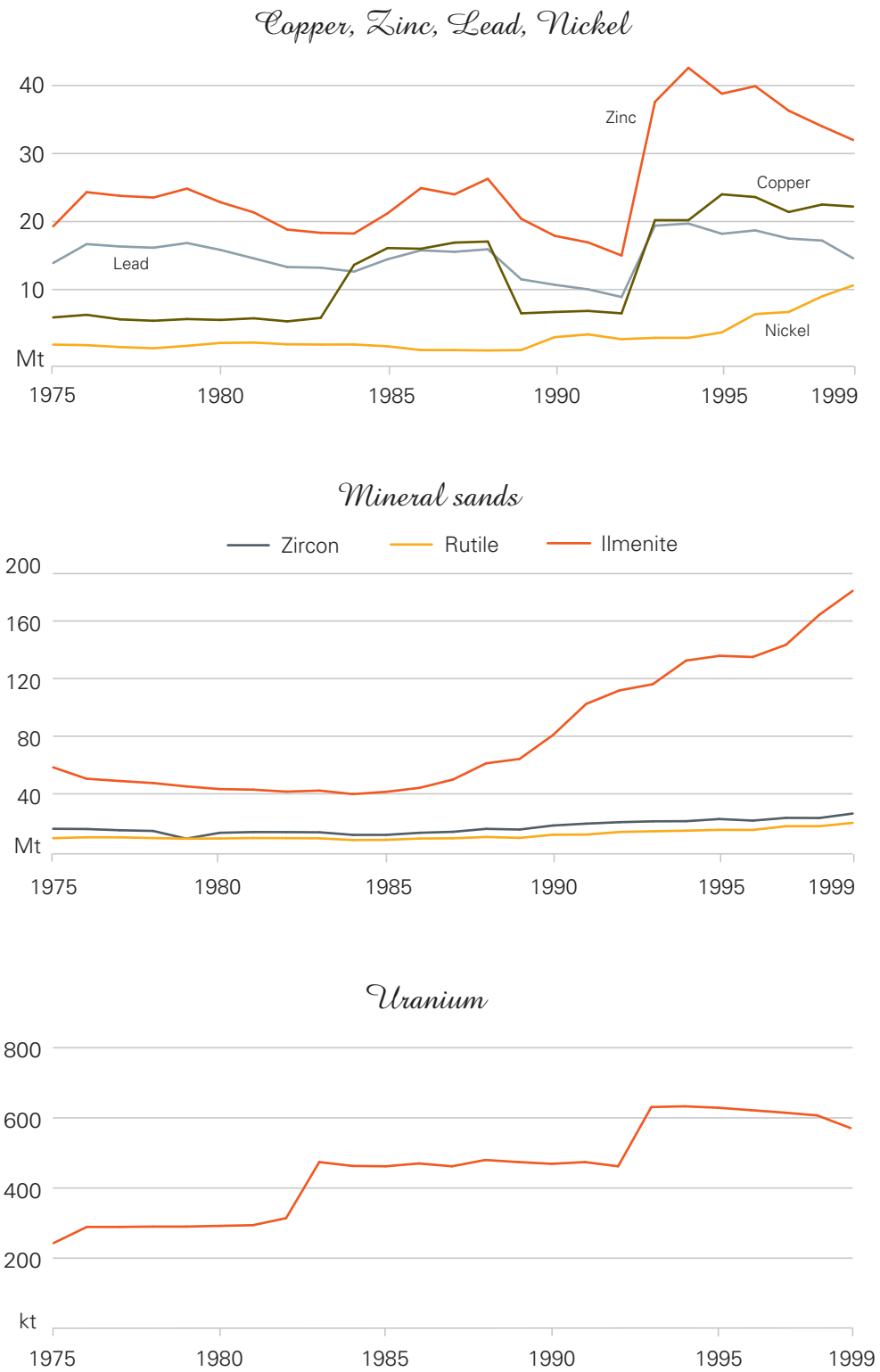


Figure 1. *continued*



All mining operations and most of the mineral deposits referred to in this section, are shown in the 2nd edition (April 2000) of the 1 to 10 million-scale map of 'Australia's mines and major mineral deposits', provided with this report (see inside back cover).

Bauxite

When exports of bauxite, alumina and aluminium (ingot metal) are taken into account, the aluminium industry is Australia's third largest merchandise exporter behind coal and gold, accounting for exports valued at around $5.9 billion in 1998-99. The Australian aluminium industry consists of five bauxite mines, six alumina refineries, six primary aluminium smelters, twelve extrusion mills and four rolled product mills. The industry directly and indirectly employs over 13 000 and 30 000 people respectively. It is particularly important in regions such as North Queensland, the Hunter Valley, Southwest Victoria, Southwest Western Australia, the Northern Territory and North Tasmania.

Resources

Vast resources of bauxite, located in the Weipa and Gove regions adjacent to the Gulf of Carpentaria and in the Darling Ranges south of Perth, underpin the long-term future of Australia's world-class alumina and aluminium industries. Deposits in these regions continue to rank among the world's largest identified resources in terms of extractable alumina content. Bauxite deposits at Mitchell Plateau and Cape Bougainville, in the north of Western Australia, are currently uneconomic to develop, but represent a significant potentially viable future resource.

EDR increased by 16% in 1999 to represent just over 37% of identified resources. On-going successful exploration programs at and nearing existing bauxite mining areas resulted in resource upgrades from the subeconomic and inferred categories.

Subeconomic demonstrated resources decreased by 4% as a consequence of reclassification of some resources to EDR. Inferred resources decreased by 35% following reclassification into the demonstrated grouping, but are expected to increase again gradually over the next few years as further drilling and field inspections are completed in Queensland and Western Australia.

Exploration

Data relating to exploration for bauxite specifically are not available nationally.

Production

In 1998-99 Australia produced 46.4 Mt of bauxite, 14.2 Mt of alumina and 1.7 Mt of primary aluminium.

World Resources and Production

Australia's demonstrated bauxite resources of 9.1 billion tonnes rank first in the world followed by those of Guinea, Brazil, India, Jamaica and China. Australia is the world's largest producer and exporter of bauxite and alumina and the third largest producer and exporter of aluminium.

Alcoas rehabilitation returns jarrah and tallowwood forest to mined areas, Western Australia
(courtesy Alcoa of Australia Ltd)

Industry Developments

In 1999, Comalco reported that its Weipa bauxite mine continued to benefit from a major plant upgrade completed in 1998 (details reported in AIMR 1999). The company has identified reductions in process variation and increased equipment effectiveness as key areas of performance improvement in its smelters. Significant productivity improvements, as measured by the reduction of energy per tonne of aluminium produced over the last five years (to less than 58 GJ/t aluminium), has contributed to increased production at lower costs.

Gladstone (Qld) has been selected by Comalco as the site for the final feasibility study for a proposed new $1.4 billion plus alumina refinery based on Weipa bauxite. The feasibility study will address the project's long term viability including commercial, technical and environmental aspects. The company announced that it expects to make a development decision in 2000.

In March 2000, CSR and Billiton Aluminium Australia signed a non-binding heads of agreement for Billiton to offer to acquire CSR's interest in the Gove alumina refinery and bauxite mine in the Northern Territory. A binding offer from Billiton was expected by mid-year.

Alcoa Inc., noting its substantial presence in Australia, announced in March 2000 that it had begun a process to list its common stock on the Australian Stock Exchange. It has a 60% interest in, and is the operator of, Alcoa World Alumina and Chemicals (AWAC). Western Mining Corporation (WMC) owns the remaining 40% of AWAC.

Black coal

Australia has substantial resources of high quality black coal. Most of these resources are located in New South Wales and Queensland, however, small but locally important coal resources occur in Western Australia, South Australia and Tasmania. Domestically, most coal production is used to generate electricity. Other uses include coke-making for the iron and steel industry, and as a source of heat in the manufacture of cement.

Resources

In-situ and recoverable EDR fell to 64.9 Gt (decrease of 8.5%) and 44.4 Gt (13.1%) respectively in 1999. This was mainly due to a major reassessment of resources particularly in New South Wales. Some resources previously considered economic were reclassified as subeconomic. Queensland with 56.2% and New South Wales with 40.4% have by far the largest share of in-situ EDR in Australia.

Subeconomic resources of black coal increased significantly in 1999 as result of the reassessment noted above. In-situ paramarginal demonstrated resources (PDR) and submarginal demonstrated resources (SDR) increased to 1.5 Gt (up by 114% from 1998) and 13.9 Gt (up by 148%) respectively. Inferred resources are very large but not quantified for Queensland and New South Wales.

Exploration

Data published by ABS shows that exploration expenditure on black coal in 1998-99 totalled $39.9 million, down from $64.8 million in 1997-98. Expenditure in Queensland and New South Wales was $22.4 million and $17.0 million respectively.

Production

In 1999, Australia produced 294 Mt of raw coal (285 Mt, 1998), which yielded 231 Mt of saleable coal (225 Mt, 1998). Exports of black coal totalled 92 Mt of metallurgical coal and 79 Mt of steaming coal. Over 70% of Australia's raw coal production came from open-cut mines.

According to ABARE projections, Australia's thermal coal exports will grow from 78.7 Mt in 1999 to 104.7 Mt in 2005. Metallurgical coal exports are projected to grow from 91.9 Mt in 1999 to 106.6 Mt in the same period.

World ranking

In 1999, Australia accounted for 6% of the world's recoverable EDR of black coal and ranked sixth after USA (28%), Russia (19%), China (12%), India (9%) and South Africa (7%). Australia produced about 6% of the world's saleable black coal output in 1999, and ranked fifth after China (34%), USA (26%), India (8%) and South Africa (6%).

Industry Developments

In Queensland, the Oaky Creek North longwall mine became fully operational. This longwall offset the loss of production resulting from the completion of open-cut operations in late 1999. The Moranbah North longwall mine commenced production in early 1999 at an initial capacity of 4 Mtpa. The Kestrel coal mine (previously Gordonstone) recommenced longwall mining at a rate of about 1.5 Mtpa. At Ensham mine, construction to increase capacity to 5.5 Mtpa was completed.

Coal fired power stations are currently being developed at Callide C, Tarong (expansion) and Milmerran. For each station, coal will be sourced from nearby low cost open-cut mines. The feasibility study for the proposed Kerlong underground operation at the Burton coal project was completed and development of a hydraulic mining operation is now under consideration. Development of an exploratory three-heading adit into the Goonyella Middle Seam commenced at Goonyella. Geological and geotechnical information from the adit should enable a decision on whether a punch longwall mine is viable. A further six large longwall areas, which could be accessed from existing highwalls, have been identified at Goonyella. The Foxleigh project has a low-ash-coal resource suitable for pulverised coal injection (PCI) and coke blending, or use as a high energy thermal coal product. A 2-Mtpa mine commenced at Foxleigh in December 1999.

Longwall at Kestrel mine, Queensland.
(courtesy Rio Tinto Ltd)

In New South Wales, the Bengalla operation shipped its first coal in April 1999, six months after the dragline commenced uncovering coal. The Hunter Valley and Howick mines merged to achieve economies of scale through one operation. New Wallsend No2 (formerly Gretley) recommenced mining, at a rate of 1 Mtpa, by revitalising the mini-longwall in the Young Wallsend seam. At Southland (formerly Ellalong), longwall mining recommenced at a rate of 2 Mtpa. Trial underground mining commenced at Glennies Creek, ahead of a decision on whether to install a longwall system.

The Donaldsons open-cut near Maitland is scheduled to commence production in 2000. Development consents have been granted for the Tahmoor North extension, Mount Pleasant, Sandy Creek (underground mine) and extensions to mining operations at Lemington and

Howick. A trial mine at Whitehaven near the old Vickery mine site is proposed. A development application has been lodged for the Newstan Life Extension Project to increase the mine life. The owners of the Mount Owen mine are proposing to expand production from 5.3 to 8 Mtpa (ROM).

In Queensland, expansion of the Dalrymple Bay Coal Terminal to 37.5 Mtpa was completed, and in New South Wales an expansion of the Kooragang Coal Terminal to 89 Mtpa has been announced. A coal terminal with an initial capacity of 20 Mtpa is proposed at Walsh Point, Newcastle. A $2.8 million coal gasifier research facility, aimed at adding value to Australian black coal resources, was opened in Brisbane.

Brown coal

Brown coal occurs mainly in Victoria with other known resources in Western Australia, South Australia and Tasmania. Victoria is the only State that mines brown coal, where extensive resources are utilised mainly for electricity generation.

Resources

Reassessment of Australia's brown coal resources during 1999 resulted in significant changes in all categories. In-situ EDR fell by 8.9% to 41.9 Gt. This resulted from some brown coal resources, previously classified as economic, being reclassified as subeconomic. Resources in the PDR and SDR categories increased with the transfer of resources from the inferred category. Victoria accounted for all of Australia's in-situ EDR, most of which is located in the La Trobe Valley southeast of Melbourne.

Exploration

Data relating to exploration for brown coal specifically are not available nationally.

Production

In 1999, brown coal production was about 66.6 Mt, up by about 3% from 1998. The La Trobe Valley produced 98.5% of Australia's brown coal.

World Ranking

Australia has about 20% of the world's recoverable brown coal EDR, and ranks second behind Germany (22%). It produced 8% of the world's brown coal in 1999 and ranked third after Germany (24%) and USA (10%).

Industry Developments

In 1999, Yallourn Energy announced it had committed $200 million on development of the Maryvale coalfield. Development activities include diversion of the Morwell River along an 8km length. This is necessary as the best quality coal lies in the vicinity of the current course of the river. Construction of the river diversion will take place over a four year period between 2000 and 2004. Overburden in the Maryvale coalfield is significantly deeper than that in the East Field, and too thick for Yallourn's existing mine overburden dredger. A truck and shovel operation is planned in 2008 to remove 'overheight' material.

Hazelwood Power is examining the possibility of moving production from its current South East coalfield, which will be exhausted in 2004, to the new West coalfield. This would extend the mine life by about 30 years.

Copper

In a global context, Australia is an important producer of copper with major mining and smelting operations at Olympic Dam and Mt Isa. Other significant copper producing mines are at Northparkes (NSW), Ernest Henry, Osborne, Mt Gordon – formerly known as Mammoth (Qld), Golden Grove and Nifty (WA).

Resources

Resource estimates for copper in 1999 are based on a partial assessment of Australia's inventory of this commodity. EDR decreased by 1.3% to 22.2 Mt and PDR by 0.6% to 17.3 Mt. SDR remained unchanged. Inferred resources increased by just under 13% with most of the addition attributable to the Olympic Dam operation in South Australia.

Exploration

Exploration expenditure for copper is not recorded separately by the ABS, being aggregated with base metals (comprising copper, lead, zinc, plus silver, nickel and cobalt). Base metals exploration expenditure of just under $177 million in 1998-99 accounted for 21.1% of total expenditure on mineral exploration.

Production

In 1999, Australia's mine production was 735 000t of contained copper, 21.7% higher than 1998. This rise is attributable mainly to increased production from the Olympic Dam mine (see below).

World ranking

Australia has the third largest EDR of copper (6%) after Chile (25%) and USA (13%).
In terms of production, Australia ranks fourth (6%) in the world after Chile (35%), USA (13%) and Indonesia (6%).

Industry Developments

A major expansion of the Olympic Dam copper/uranium/gold/silver operation in South Australia was completed in the first quarter of 1999 at a cost of $1.94 billion. The expansion increased copper production from 85 000 tpa to 200 000 tpa (nameplate capacity) ahead of schedule in September 1999.

In Western Australia, resources at the Wandoo project increased and incorporated an initial estimate for Wandoo North and a re-estimate of Wandoo South. The current feasibility study for this project has identified several innovative flowsheet improvements over the original 1997 study, particularly with regard to the crushing and grinding operation. Pilot testing in 2000 will extend the duration of the study. At Golden Grove, deeper drilling at the Scuddles and Gossan Hill mines intersected extensions of zinc and copper mineralisation, which could extend the life of these operations. At Nifty, expansion of SX-EW copper cathode production from 16 500 to 25 000 tpa is expected to be achieved by late 2000. Straits Resources NL has commenced studies aimed at facilitating development of the Nifty sulphides around 2002. The company is also examining integration of Maroochydore ore into the Nifty flowsheet. Straits Resources NL is also re-evaluating options for development at Whim Creek (WA).

In Queensland, commissioning of MIM's Enterprise copper mine at Mt Isa was well advanced at the end of 1999, and Western Metals Ltd completed major modifications to its Mt Gordon processing plant. The company has applied for a world patent over the 'Mt Gordon process', being the only technology in the world that utilises pressure oxidation/ferric leaching for copper sulphides.

In New South Wales, the $286 million Ridgeway underground mine is scheduled to be operating by the end of 2001. In Tasmania, India's Sterlite Industries purchased the Mt Lyell operation and has announced plans to invest $10 million to resume underground development.

Diamond

Resources

In 1999, EDR of 82.4 Mc for gem/near gem diamond and 85.5 Mc for industrial diamond were both up by over 20% compared to the previous year. However, Australia's total identified resources for gem/near gem (302 Mc) and industrial (325 Mc) diamond both fell by 2%. Production offset by delineation of new resources at Argyle in Western Australia accounted for most of these changes.

Despite production of 27.8 Mc, Argyle's ore reserves and mineral resources (in terms of contained diamond) remained virtually unchanged compared to 1998.

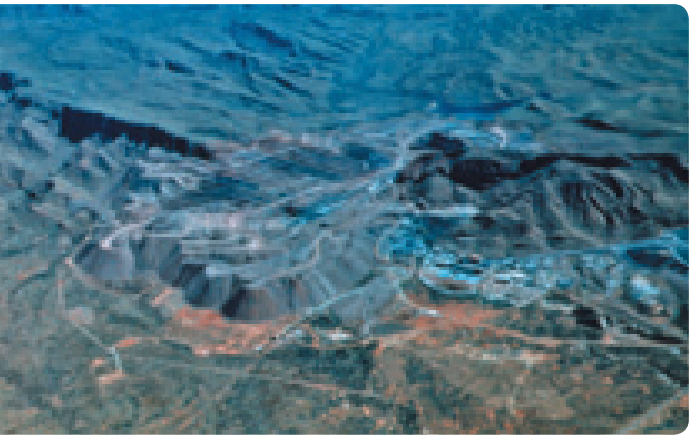
Exploration

In 1999, $34 million was expended on diamond exploration in Australia, 26% less in 1998.

Production

Production of diamonds (gem/near gem, industrial) in 1999 was 30.8 Mc, a fall of 10 Mc against 1998. Most of the decrease resulted from an increased waste-to-ore ratio associated with expansion of the open-pit at Argyle.

Australia's diamond production is the largest in the world for both the gem/near gem and natural industrial diamond categories. Production is mostly from the Argyle open-pit with a lesser contribution from the nearby Argyle alluvials operation. Minor production was also recorded from the Merlin (NT) and Copeton (NSW) mines.



Argle diamond mine, Western Australia.
(courtesy Rio Tinto Ltd)

World Resources

Australia's EDR of industrial diamond are the world's third largest (15%), after the Republic of Congo and Botswana. Detailed data are not available on world resources of gem/near gem diamond but Australia has one of the largest stocks for this category.

Industry Developments

Expansion of the Argyle open-pit continued with stripping of the West Wall to gain access to more ore at the base of the pit. A new area of diamond mineralisation, intersected in four deep drill holes behind the Razor Back Fault, is open at depth beneath the southern end of the open-pit. Much of this mineralisation has yet to be quantified and included in the mine's resource statement. Alluvial production decreased due to the increased clay content of ore from the Smoke Creek system.

At the Merlin operation, 2.9 Mt has been delineated as an inferred resource. During 1999, diamond production totalled 83,745 carats. All four open-pit mines in the southern cluster of kimberlite pipes yielded diamonds in excess of 10 carats, with the largest stone being a 27.5 carat gem-quality diamond from the Palomides mine. The average sale price for diamond mined in 1999 was $US128 per carat, which was significantly greater than the average price of $US75 per carat determined from the mining feasibility study bulk sampling. This has more than offset lower grades, which were encountered during mining.

Gold

Much attention in the Australian gold mining industry during 1999 was focussed on the low US dollar price for gold. An improvement in that price late in the year provided the industry with a degree of optimism. Although there was a reduction in exploration spending, in line with international trends, programs again yielded new resources and prospects. While substantial resources were added at some known deposits, resources were announced for the first time at others and encouraging drill intersections were reported from new prospects. In terms of identified resources, substantial growth led to a record level of total resources being achieved - despite production again exceeding 300 t.

Resources

Australia's gold resources occur in and are mined in all States and the Northern Territory. Total Australian resources rose by 514 t (16.5 Mozs) in 1999. After allowing for replacement of resources lost to production, total newly delineated resources added to the national inventory during the assessment period was just over 816 t (26.2 Mozs). Resources rose in Tasmania, Western Australia and the Northern Territory.

Australia's EDR rose by 614 t (19.7 Mozs), an increase of 14% over 1998, to 5018 t. This was a record EDR, surpassing the previous high established in 1996 by almost 13%. EDR is the sum of the JORC Code reserves categories and those resources from the measured and indicated resource categories assessed by AGSO as likely to be economic. Just over half the EDR fell into the JORC reserves categories.

Western Australia's dominance of EDR grew with an increase of 590 t to the record level of 3137 t (63% of Australian EDR). South Australia had the second largest and the combined Western Australian and South Australian EDR accounted for 80% of the Australian total. While New South Wales retained its position as the third largest EDR, it fell by 9 t to 452 t (a drop of 2%). An increase of almost 52% in the Northern Territory EDR to 244 t saw it again become the fourth largest EDR ahead of Queensland, which had a 19 % fall to 197 t. Much of the improved position in the Northern Territory can be attributed to the reinstatement of resources at Yimuyn Manjerr (formerly Mount Todd) to EDR following the decision to reopen the mine. Victoria's EDR fell by 1 t to 71 t and in Tasmania the fall was just over 2 t to about 48 t.

Some 82% of demonstrated resources occur in EDR compared with 77% in 1998. The increase was caused by the combined impact of new discoveries and some improvement in the gold price.

Subeconomic demonstrated resources fell by 3% to 1281 t. The reduction was entirely due to a fall of 201 t in the paramarginal category - largely because the improved gold price allowed some paramarginal resources to be upgraded to EDR. Although Western Australia dominated paramarginal resources, with 599 t, its share fell from 68% to 60%. Paramarginal resources increased in Tasmania (up by 24 t to 40 t) and New South Wales (up by 18 t to 87 t). Falls were recorded in Queensland (down by 7 t), Victoria (down by 5 t) and the Northern Territory (down by 16 t) as well as the reduction in Western Australia.

Only minor movements occurred in the submarginal demonstrated resource category where there was an overall increase of 1 t to 125 t. In Western Australia, an increase of just under 2t occurred but movement in all other states and the Northern Territory was of 1t or less.

Inferred resources rose by 98 t (4%) to 2568 t in 1999. Increased inferred resources were recorded in Western Australia (up by 7% to 1736 t), the Northern Territory (up by 6% to 174 t), and Queensland (up by 3% to 161 t). In New South Wales, inferred resources fell by 14% to 162 t. Reductions in other States were minor with Tasmania's inferred resources falling by just under 3 t and Victoria and South Australia's by less than 1 t each. Over half of the increase in Western Australia can be attributed to new resources announced for the Wandoo project.

The ratio of demonstrated to inferred resources showed a marginal increase from 2.3:1 to 2.4:1. In comparison to the ratio for the last decade this is toward the top of the range.

Exploration expenditure

According to the four 1999 quarterly exploration expenditure data published by ABS, Australian exploration expenditure in 1999 was $719 million, a reduction of $239 million (25%) over 1998. Of the total, $404 million (56%) was spent on the search for gold. This was a reduction of $158 million from 1998.

Production

Preliminary production data from ABARE indicate that Australia's gold production in 1999 fell by just under 4% to 301 t. Western Australia remained the dominant producer with an output of 213 t (9% lower than in 1998), which was almost 71% of total Australian output. Queensland remained the second largest producer with just under 33 t, which was a little more than in 1998. Other production (in rounded amounts) was: Northern Territory 22 t, New South Wales 21 t, Tasmania 5.5 t, Victoria 4.5 t and South Australia 2 t.

Nancy decline portal, Queensland
(courtesy Normandy Mining Ltd)

New South Wales again reported solid growth in output with an increase of 38% from 1998, due largely to the operations at Cadia.

World Ranking

Based on figures published by the USGS and modified to incorporate the Australian resources reported here, Australia has now the fourth largest EDR after South Africa, USA and Uzbekistan. The USGS reported that Uzbekistan had EDR of 5300 t compared with only 2000 t reported in 1998. That growth was sufficient to allow it to pass Australia and move into third position in the ranking.

World EDR in 1999 was 50 018 t of which South Africa accounted for 38% down from the 41% it enjoyed in 1998. The USA's share was down slightly to 11% (12% in 1998). From only 4% in 1998, Uzbekistan's share rose to just under 11% in 1999. Despite dropping on place in the rankings, Australia maintained its share of world EDR at 10% for the year. Russia followed Australia and had 6% of the total EDR.

The USGS report total world gold production in 1999 at an estimated 2330 t. Production rankings remained unchanged with South Africa being the largest producer with 19.3% (450 t) of world output – about the same as in 1998. It was followed by the USA, whose share was unchanged at 14.6% (340 t) and Australia with an unchanged 13% (302 t). Canada retained

fourth position with a reported output of 155 t (6.7%) of the world total.

Industry developments

Activity was still at a relatively high level in 1999 and exploration successes were recorded.

The Boddington (WA) joint venture partners announced, in August, a significant increase in resources at the Wandoo project. Total resources contained 15.34 Mozs of gold. Resources by category are: – measured, 86 Mt at a grade of 1.17 g/t Au and 0.11% Cu; indicated, 223 Mt at a grade of 1.06 g/t Au and 0.13% Cu; and inferred, 132 Mt with a grade of 1.10 g/t Au and 0.09% Cu. The feasibility study for the project has increased plant throughput to 18 Mtpa and is expected to see production approach 0.5 Mozs at lower cash costs. Pilot testing of some of the potential improvements will extend into the first half of 2000.

Pacmin Mining Corporation Ltd. announced an 84% increase in gold at its Carosue Dam project (WA) to 2.2 Mozs, contained in 40.1 Mt of ore at an average grade of 1.7 g/t Au, in three deposits, Karari, Whirling Dervish and Luvironza. Over half of the total contained gold is in Karari. Pacmin reported that 1.039 Mozs are in the probable reserve category. Following the successful outcome of a pre-feasibility study, Pacmin decided to proceed to a comprehensive, bankable feasibility study. The company also announced that following negotiations with Native Title claimants, agreement had been reached with all parties and that mining leases had been formally applied for.

Taipan Resources N.L. released the findings of a feasibility study into the development of its Paulsens project. The study indicated that 402 000 ozs could be produced over a four year mine-life at an average cash operating cost of $217/oz. The deposit has an indicated resource of 1.437 Mt with an average grade of 8.7 g/t Au and an inferred resource of 1.128 Mt at a grade of 6.0 g/t Au. The company also reported that a probable reserve of 1.050 Mt with a grade of 8.78 g/t Au was derived from the indicated resource. Metallurgical investigations have shown that the ore is amenable to conventional carbon-in-leach treatment. Production from an underground mine is expected to commence 15 months after commitment to the project is given.

New gold resource estimates for the East Kundana project (WA - Gilt-Edged Mining N.L., Tribune Resources N.L. and Rand Exploration N.L.) culminated in an estimate of 777 000 ozs being released in December. The resources occur in the Hornet, Rubicon and Pegasus deposits. At a 1 g/t cut-off grade, resources in the deposits are:

Hornet - measured 417 000 t at 5.4 g/t Au, indicated 622 000 t at 11.9 g/t Au, inferred 165 000 t at 8.5 g/t Au;

Rubicon - measured 440 000 t at 9.1 g/t au, indicated 672 000 t at 4.7 g/t Au, inferred 421 000 t at 2.8 g/t Au;

Pegasus - indicated 189 000 t at 2.0 g/t Au, inferred 996 000 t at 3.9 g/t Au.

Gilt-edged Mining have reported that these results will be incorporated into the project's preliminary scoping study process.

In October, Sirocco Resources N.L. poured the first gold from its Quest 29 project at the refurbished Tom's Gully CIL plant in the Northern Territory. The company anticipates that when ore is also sourced from the Tom's Gully underground mine, production should increase to a rate in excess of 40 000 ozs per annum.

At the end of the year, Queensland Government approval was given for additional land area in one of the key mining leases at Mount Rawdon. In principle approval was also received for the proposed tailings dam design and management systems.

Two factors resulted in a total of 61 000 ozs of gold being removed from the Kidston mine's (Queensland) inventory. Kidston Gold Mines Limited conducted trial processing of 200 000 t of stockpiled mineralised waste. The grade and recovery rates were lower than expected and this caused 28 000 ozs to be removed from the inventory. Work to rectify pit wall stability at the Eldridge Pit necessitated a revision of the mine plan, and resulted in the sterilisation of some ore with the loss of 33 000 ozs from the mine's reserves.

Exploration drilling conducted in various areas of Australia provided many encouraging intersections. The following examples indicate the variety and geographic dispersion of the intersections.

In the Laverton region of Western Australia, the Laverton Exploration Joint Venture (Delta Gold N.L. 50% and Metex Resources N.L. 50%) reported a new prospect at Red Flag. Anomalous flat-lying gold mineralisation, interpreted as a supergene blanket, was outlined over a strike length of 200 metres and width of 200 metres, with a maximum true thickness of 15 m. The zone is open in all directions and the Joint Venturers report a best intersection of 7 m at a grade of 3.16 g/t Au. The mineralisation is hosted by porphyry intruded sediments in a zone of intensive quartz veining.

A series of announcements by LionOre Mining International Pty Ltd and Dalrymple Resources N.L. reported encouraging drill results from the Thunderbox gold discovery in Western Australia. Typical intersections included 20 m at 2.21 g/t Au, 12 m at 3.38 g/t Au, 10 m at 3.21 g/t Au and 10 m at 2.44 g/t Au. Mineralisation occurs in both primary and oxide zones. The companies report that preliminary cyanide leach testwork was undertaken to help identify potential metallurgical problems in the primary zone ore, which may have up to several per cent arsenopyrite/pyrite. Results of this work found the gold leaches readily and is not locked into the sulphide minerals.

The Granny Smith Joint Venture (Placer Pty Ltd and Delta Gold N.L.) reported successful drill intersections from the Merolia exploration licence, which is wholly owned by Golden Cross Resources N.L. From three drillholes, the best intersection reported was 12 m at a grade of 6.04 g/t Au. Mineralisation is interpreted to be related to quartz veining in a strongly foliated shear zone in a lithology of predominantly mafic basalt. Merolia is located some 30 km northeast of the Granny Smith mine.

In Victoria, exploration at Stawell Gold mines intersected a repetition of the mine sequence (3.2 metres at 4 g/t Au) below the fault which truncates the orebody. At Fosterville, Perseverance Corporation outlined 18 Mt at 1.7 g/t Au of sulphide ore, which it plans to treat by bacterial oxidation. Bendigo Mining's Swan decline, under the city of Bendigo to access a resource with the potential to reach 10 Mozs, reached 650 metres – half its planned depth.

Other promising drill intersections reported during the period under review are summarised in Table 2.

Table 2. Intersections of gold mineralisation in 1999.

Company	State	Prospect	Intersections	Locations
Acacia Resources	**WA**	Coyote	6 m at 16.3g/t Au 15 m at 17.0 g/t Au	WA, extension of the Tanami gold province
Otter Gold Mines	**NT**	Camel Bore	7 m at 18.7 g/t Au 26 m at 5.44 g/t Au	Near the Tanami gold operation
Normandy NFM	**NT**	Ground Rush	22 m at 19.9 g/t Au inferred resource of 3.3 Mt at 4.5 g/t Au	100km from The Granites
Normandy NFM	**NT**	Wilson Shoots	Down plunge extensions of orebody	Callie deposit (4.6 Mozs of gold)
Pacmin and Normandy	**NT**	Chariot	14.9 m at 37 g/t Au 13.8 m at 12.3 g/t Au 3 m at 13.3 g/t Au	Near Tennant Creek
Defiance Mining	**TAS**	New Golden Gate Mine-and New Reefs	2.0 m at 24.8 g/t Au 2.0 m at 13.2 g/t Au	NE Tasmania
Sedimentary Holdings and Newcrest	**QLD**	Roses Pride	14 m at 15 g/t Au 13 m at 7.4 g/t Au	Cracow
Pasminco and Werrie Gold	**SA**	Benagerie	6 m at 42.2 g/t Au	Curnamona Province
MIM, Western Metals and Normandy	**SA**	White Dam	72 m at 2.6 g/t Au and 32% copper	Curnamona Province

Iron Ore

Iron ore is the raw material for the production of iron that is mostly further processed to produce steel. Although the production of iron and steel accounts for most of the iron ore consumed in Australia and the rest of the world, small tonnages are used in a variety of applications - including pigment manufacture, coal washeries, and cement manufacture.

Over 90% of Australia's iron ore resources occur in Western Australia, mostly in the Hamersley Basin in the Pilbara region. Small but locally significant resources occur in South Australia, Tasmania and New South Wales. Australia's large iron ore resources are the basis of a major export industry, which is based mainly in the Pilbara.

Resources

EDR increased 1.5% to 15.5 Gt in 1999 mainly as a consequence of new resource data becoming available for Robe River and Weld Range. Western Australia has 99.5% of Australia's EDR. PDR fell slightly and SDR increased by over 200% mainly through the inclusion of resource data for the Ooldea deposit in South Australia. Inferred resources increased 41% mostly through the inclusion of the Fortescue (WA) deposit.

Exploration expenditure

According to ABS data, exploration expenditure for iron ore in 1998-99 totalled $41.5 million, up from $30.0 million in 1997-98.

Production

Australian iron ore production in 1999 was 155.0 Mt (155.7 Mt in 1998). Of the total production, 148.8 Mt (96.0%) was from Western Australia with exports (reported by ABARE) to be 139.6 Mt and valued at $3600 million.

ABARE expects Australian iron ore exports to increase by over 16% to around 175 Mt by 2004-05. Over the same period Australian production is forecast to increase to 193.5 Mt.

World ranking

Australia has some 11% of world EDR of iron ore and is ranked fourth after China (18%), Ukraine (16%) and Russia (15%). In terms of contained iron, Australia has some 13% of the world's EDR and is ranked third behind the Ukraine (17%) and Russia (15%). Australia produces some 15% of the world's iron ore output and is ranked third behind China (21%) and Brazil (19%).

Yandicoogina iron ore mine (HI Yandi), Western Australia
(courtesy Rio Tinto Ltd)

Industry Developments

BHP Ltd's Hot Briquetted Iron (HBI) facility at Port Hedland (WA) commenced commissioning in February 1999. Following continued commissioning difficulties throughout the year, BHP (4 May 2000) announced a writeoff of $1138 million before tax ($794 million after tax) in the carrying value of the HBI plant. The company is continuing to pursue solutions in order to improve production reliability from the plant. These include development of a detailed project plan for the implementation of a number of technical modifications to existing facilities. A final decision on the company's continued retention of the facility is expected by the end of 2000.

BHP announced that it proposes to develop Mining Area C with an initial capacity of about 5 Mtpa of Marra Mamba ore. This operation would be located 35 km south of its Yandi operation.

Hamersley Iron Pty Ltd's HiYandi mine dispatched its first ore shipment to Japan in January 1999. With a design capacity of 15 Mtpa, the HiYandi mine is extracting a channel iron deposit consisting of goethite/hematite ore with a low alumina content, which is particularly suited to sinter plants. The HiYandi development required a 147 km rail line extension, upgrading of loading and stockpiling facilities at Dampier and dredging of the channel and parking basins. At Nammuldi/Silvergrass, Hamersley plans to develop two deposits at a total capital cost of $300 million. The deposits are near its Brockman No 2 operation and the existing loadout facilities and rail spur will be utilised.

Robe River Iron Associates announced that they would develop the West Angelas deposit with an initial capacity of 7 Mtpa commencing in 2002. The company has planned a staged expansion to its 20 Mtpa open-cut operation based on mining Marra Mamba ore from Deposits A and B initially with potential to incorporate Deposits C to H. Construction of a 340 km rail link between West Angelas and Cape Lambert, and an upgrade of port facilities are also required. About one third of the production will be lump ore. West Angelas represents the first major development of unblended Marra Mamba ore.

Portman Mining Ltd acquired additional leases at Bungalbin about 40 km north of Koolyanobbing (WA). The company also secured the Mount Jackson and Windarling leases, which are about 80 km north of Koolyanobbing. Portman plans to increase production from from 2 to 6 Mpta at Koolyanobbing following the Esperance Port Authority's commitment to deepen the harbour to allow vessels of up to 160 000 t to be loaded. The Authority will also upgrade the loading operation and construct additional storage areas for iron ore. At Cockatoo Island, Portman has announced its intention to extend the life of the project, with a two year remnant ore operation, that will supply a new high grade sinter fines product.

Kingstream Steel Ltd acquired the Weld Range and Jack Hills leases to extend the iron ore resources for its proposed Mid-West Iron and Steel Project at Geraldton, north of Perth. At Hope Downs, Hancock Prospecting completed a drilling program in early 1999 that provided samples for metallurgical and customer test work. A feasibility study is scheduled to be completed in 2000.

At Savage River in Tasmania, Australian Bulk Minerals moved its primary crusher into the pit to enable a series of cutbacks to be completed. This should achieve a planned 20-year mine life. It is also intends to redirect the Savage River to open up an area of high-grade ore.

In South Australia, AuIron Energy (formerly Meekatharra Minerals) signed a contract with Thiess Contractors to build a $16 million pig-iron demonstration plant near Whyalla as part of the South Australia Steel and Energy project. Construction is scheduled to be completed in July 2000. Successful operation of the demonstration plant could lead to the construction of a $1 billion pig-iron smelter near Whyalla or Coober Peddy.

Lithium

Lithium is a silvery grey metal with a density about half that of water. Sons of Gwalia's Greenbushes mine in Western Australia is the world's largest producer of lithium minerals. Greenbushes products have a range of uses that include production of specialty glasses, ceramics, ceramic glazes and glass bottles. Its ore (predominantly spodumene $Li_2OAl_2O_34SiO_2$) is also a feedstock for the production of lithium carbonate in the chemical industry.

Resources

All of Australia's identified lithium resources are in Western Australia and all EDR occur in the Greenbushes deposit, in the southwest of the State. EDR fell slightly to just over 156 000 t in 1999, mainly through depletion of resource to production. Greenbushes is the world's largest and highest grade spodumene deposit. Subeconomic demonstrated resources and inferred resources were unchanged in 1999.

Exploration

There are no statistics available on exploration expenditure for lithium. In view of the current world oversupply of lithium resources, particularly in the form of lithium rich brines especially in Chile, it is unlikely that there will be substantial expenditure on exploration in Australia in the near future.

Production

Sons of Gwalia Limited remained the world's largest producer of lithium minerals in 1999. Production for the year was 75 824 t of lithium minerals, which was about 20% higher than 1998, but sales of lithium minerals fell by 21%. Reduction in sales followed significant continuing oversupply in the world lithium carbonate market that stems from production at brine operations in Chile and Argentina.

World Resources and Production

According to estimates published by the USGS, Chile holds approximately 88% of the world's lithium resources, followed by Canada with just over 5%, and Australia with just under 5%. Resource data, however, are not available for some important producing countries including Argentina, China and Russia. Lithium resources occur in two distinct categories – lithium minerals and lithium rich brines. Lithium brine resources, now the major feedstock for lithium carbonate production, are produced dominantly by Chile. Canada and Australia have the most significant resources of lithium minerals.

World production of lithium in 1999 was estimated by the USGS to be 15 000 t of contained lithium, unchanged from 1998. However, information on USA production is withheld by the USGS for commercial reasons. Production increases in 1999 occurred in Argentina (up by 70 t to 1200 t) and Chile (up by 300 t to 5000 t), but these were offset by falls in production in China (down by 500 t to 2500 t) and Russia (down by 200 t to 1800 t). Chile with 33% remained the world's largest producer, followed by China (17%), Australia (14%) and Russia (12%).

Industry Developments

There were no significant developments in Australia's lithium sector in 1999. Faced by continuing price and volume pressure from substantial world oversupply, Sons of Gwalia reported that sales of its lithium minerals fell by 17% in 1998-99. The company also announced that in order to reduce stockpiles, its lithium minerals plant would be used to treat tantalum tailings and to conduct pilot plant studies on tantalum recovery for part of 1999-00.

Magnesite

Although magnesite deposits occur in all Australian States, magnesite is only mined in substantial quantities in Queensland. Virtually all mine production is calcined to magnesia for used as refractory and non-refractory materials.

Resources

EDR of magnesite rose by 18% to 246 Mt in 1999. All of the increase occurred in South Australia (which has the highest EDR), where SAMAG Ltd (80% owned subsidiary of Pima Mining NL) has identified a global resource in excess of 600 Mt magnesite in the Willouran Ranges northwest of Leigh Creek. Some 50 Mt of this resource, at Mount Hutton and Witchelina (with grade over 42% MgO), has been classified as EDR.

Queensland has the largest inventory of magnesite EDR, with most at Kunwarara (70 km northwest of Rockhampton). A fall in Kunwarara's EDR resulted from a combination of loss to production and reclassification of ore reserves by the company. The Kunwarara deposit contains substantial accumulations of very high-density 'bone-type' magnesite, which is characterised by nodular and cryptocrystalline structure, and low iron content.

The Thuddungra mine, 80 km northwest of Young in New South, continued on care- and-maintenance throughout 1999. Magnesite from this mine, which typically contains 98-99% $MgCO_3$ is processed at Young when produced.

The third largest inventory of magnesite EDR is in Tasmania, where the Arthur River deposit contains an indicated resource of 29 Mt of magnesite. The magnesite grades 42.8% MgO and is part of a much larger global resource of 180 Mt in the Arthur-Lyons River area, about 53 km south of Burnie. A small EDR of magnesite occurs in the Ravensthorpe area in southeast Western Australia.

Subeconomic demonstrated resources, which account for around 70% of total identified resources rose by 85 Mt during the year. Most of the rise was in PDR and recorded in South Australia and Tasmania. SDR of magnesite totalled nearly 360 Mt, an increase of 4% over the previous year. The increase resulted from reclassification of resources by industry. All these resources are in Queensland.

Inferred resources rose by 56% to a new record level of 736 Mt in 1999. South Australia and Tasmania recorded the largest increase as a result of recent discoveries. South Australia with 63% is the main holder of inferred resources followed by Tasmania (20%) and Queensland (14%).

Exploration

Data relating to exploration for magnesite are not available nationally.

Production

During 1999, Queensland Metals Corporation Limited mined some 2.4 Mt of crude magnesite ore at Kunwarara, which was beneficiated to produce about 279 500 t of magnesite. This material was used to produce 89 896 t of deadburned magnesia, about 37 200 t of calcined magnesia, and 19 890 t of electrofused magnesia. These products are used in the manufacture of high-quality refractory bricks, which are for lining heat-containment vessels in the steel, cement, non-ferrous and chemical industries.

World ranking

According to USGS estimates, Australia has about 2% of the world's EDR of magnesite. China, Russia and North Korea together account for over 70% of the world's EDR of magnesite. However, the Kunwarara deposit is the world's largest known resource of cryptocrystalline, nodular magnesite, a high-quality ore by world standards.

Australia accounted for 3% of the world's production in 1999. According to USGS estimates, China (at 24%) was the world's largest producer, followed by North Korea (16%) and Turkey (10%).

Industry Developments

In August 1999, Australian Magnesium Corporation (AMC) produced the first batch of magnesium ingots from its 1500 tpa magnesium metal demonstration plant near Gladstone. A decision on whether to proceed with a $1 billion, 90 000 tpa commercial plant is expected in 2000. Should it proceed, magnesium metal production from the plant is expected to commence in late 2002.

In Tasmania, Crest Magnesium NL continued with its feasibility study into mining the Arthur River magnesite deposit. The company has negotiated an option to acquire a license to use magnesium metal production technology from the Ukrainian National Research and Design Titanium Institute (UTI), Zaporozhie, Ukraine.

Golden Triangle Resources NL reported that its Woodsreef serpentinite to magnesium project had the potential to deliver lower operating costs than its magnesite-based projects. The company has also reported that it plans to use the Alcan dehydration and Canadian Noranda Inc electrowinning technology for the Woodsreef project

In the Northern Territory, Mt Grace Resources NL has secured the rights to use the Heggie metallothermic process technology to recover magnesium metal from calcined magnesite. The company plans to build a demonstration plant to test the process on its Batchelor magnesite deposit located some 80 km south of Darwin. If successful, the company plans to produce magnesium metal by building a 5000-tpa plant in modules based around this technology.

In South Australia, SAMAG Ltd (Pima Mining NL 80% and Resource Finance Corporation Ltd 20%) has acquired magnesium processing technology from Dow Chemical Company of the USA. The company's plant at Freeport, Texas, was the world's largest magnesium metal production facility until it closed in 1998. The SAMAG project plans to use its magnesite resources in the Willouran Ranges, northwest of Leigh Creek, to produce magnesium metal from a 52 500-tpa plant located near Port Augusta.

Manganese Ore

Manganese ore occurs in all States and the Northern Territory. Most resources are located on Groote Eylandt in the Northern Territory. Small but locally significant resources occur at Woodie Woodie and Ant Hill in Western Australia. Australia's manganese resources are the basics of an important export industry as well as a domestic ferromanganese, silicomanganese and manganese dioxide industry.

Resources

EDR rose by over 22% to 134.3 Mt in 1999 due to new resource data becoming available for Groote Eylandt and the recommencement of the Woodie Woodie project in Western Australia. PDR fell by 14.3% and inferred resources increased 12.6%. These changes were mainly due to a major reassessment of manganese resources.

Exploration expenditure

Data relating to exploration for manganese are not available nationally.

Production

In 1999, Australia produced 1.9 Mt of manganese ore with a manganese content of 0.9 Mt. Exports totalled 1.4 Mt, valued at $195 million.

World ranking

Australia has 7% of the world's EDR of manganese ore and is ranked fourth behind South Africa (46%), Ukraine (24%) and China (11%). In terms of contained manganese, Australia has 9% of the world's EDR and is third behind South Africa (52%) and Ukraine (19%). Australia is the fifth largest producer at 9% behind China(30%), South Africa(15%), Gabon(11%) and Ukraine(10%).

Industry Developments

In Western Australia, Consolidated Minerals Ltd re-opened the Woodie Woodie mine in the Pilbara with an initial shipment of 35 000 t of ore to Europe in August 1999. The mine has a capacity of 250 000 tpa of lump ore and 50 000 tpa of fines. Mining took place at the Big Mack and Extension Cord deposits and the company increased its resource base by acquiring the 'Bell's Pit' leases adjacent to Woodie Woodie.

Hitec Energy NL (formerly Sovereign Resources NL) is planning to develop the Hitec

manganese project based on the Ant Hill deposit near Nulligine, 320 km southeast of Port Headland (WA). Hitec have entered into an option agreement to purchase manganese ore from Woodie Woodie. The company plans to construct an electrolytic manganese dioxide (EMD) and manganese sulphate plant at Port Hedland. Pilot plant testing to evaluate production of EMD commenced in late 1999.

Mineral sands

The principal components of mineral sands are zircon and the titanium minerals rutile and ilmenite. Rutile and ilmenite are used mainly in the production of titanium dioxide pigment with a small portion, less than 4% of total titanium mineral production, typically rutile, used in making titanium sponge metal. Zircon is consumed as an opacifier for glazes on ceramic tiles, in refractories and for foundry industry.

Resources

EDR of ilmenite increased substantially during 1999, up from 164.3 Mt in 1998 to 180.9 Mt, an increase of just over 10%. Most of the increase (86%) occurred in Western Australia, which has largest EDR, and resulted from infill drilling along the northern section of the Swan Coastal Plain.

Queensland, with the second largest EDR (26%), recorded minor increases in EDR. Both New South Wales and Victoria, which have about 1% each of total EDR, recorded small increases.

EDR of rutile (which includes leucoxene in WA) increased substantially from 17.5 Mt in 1998 to 19.9 Mt in 1999. Most of the increase (99%) occurred in the northern Swan Coastal Plain. Queensland and Western Australia together have over 85% of the Australia's EDR of rutile.

EDR of rutile in Victoria and New South Wales increased marginally, all in the Murray Basin.

EDR of zircon increased substantially from 23.2 Mt in 1998 to 26.3 Mt in 1999. The bulk of the increase occurred in the northern Swan Coastal Plain. In New South Wales, EDR increased by 2% and remained unchanged in Victoria. Western Australia and Queensland together have 87% of Australia's EDR of zircon.

Some 17%, 23% and 28% of Australia's EDR of ilmenite, rutile and zircon, respectively, are unavailable for mining. Areas quarantined from mining and now largely incorporated into national parks include: Moreton, Bribie and Fraser Islands; Cooloola sand mass north of Noosa; Byfield sand mass and Shoalwater Bay area in Queensland; and Yuraygir, Bundjalung, Hat Head and Myall Lakes National Parks in New South Wales.

Australia's subeconomic demonstrated resources of ilmenite, rutile and zircon increased marginally to 66.0 Mt, 36.4 Mt, and 27.3 Mt, respectively in 1999. This occurred in the Murray Basin in New South Wales and South Australia and all in the paramarginal category.

Inferred resources of ilmenite rose by 8.3% to 112.3 Mt in 1999. Increases occurred in New South Wales, Victoria and South Australia. Victoria is the main holder of the inferred ilmenite resources with 39% of the Australian total. Western Australia with 27%, has the second largest inferred resource followed by Queensland with 21%.

Inferred resources of rutile and zircon increased by 7% and 5%, respectively. The bulk of the increases occurred in New South Wales and Victoria with a small increase in South Australia. Victoria is the main holder of rutile and zircon inferred resources with 77% and 61%, respectively. Queensland with 8% and 14% respectively, is the second largest holder of these resources.

Exploration

According to quarterly ABS figures, expenditure on exploration for mineral sands in 1999 was estimated at $18.2 million. This is an increase of about 5% over the previous year. Comprehensive State-by-State data are not published by ABS, but it is likely that most of the expenditure was in the Murray Basin, which has an extensive coverage of exploration leases.

Production

In 1999, Australia produced 2.0 Mt of ilmenite, 190 000 t of rutile and 375 000 t of zircon. The bulk of Australia's rutile and zircon production is exported compared to about 55% for ilmenite. Remaining ilmenite is upgraded to synthetic rutile, which contains about 92-93% TiO_2.

World ranking

According to AGSO and USGS data, Australia has the world's largest EDR of ilmenite, rutile and zircon with 29%, 42%, and 39% respectively. Other significant rankings are South Africa (19%) and Norway (11%) for ilmenite; South Africa (19%) and India (15%) for rutile; and South Africa (35%) and Ukraine (10%) for zircon.

In 1999, world production of ilmenite decreased by 6% to 6.3 Mt, rutile by 12 % to 381 000 t, and zircon by 1% to 790 000 t. Australia produced about 31%, 50% and 47% each of world production of ilmenite, rutile and zircon respectively, and is the world's leading producer of all three minerals as well as the largest exporter. South Africa (from dune sands) and Canada (from hard rock) mine similar quantities of ilmenite to Australia, and upgrade it to titanium slag before exporting.

Industry Developments

Iluka Resources' Gordon mine on North Stradbroke Island ceased operations in early 1999 following extraction of the resources. The dredge and concentrator were relocated to the Yarraman deposit and re-commissioning of the plant commenced in October.

Westralian Sands Limited merged with RGC to form Iluka Resources Ltd, which has become the world's second largest producer of titanium mineral feedstocks for the pigment industry, and the largest producer of zircon for ceramics and refractory industries. As a result of the merger, mining and processing operations at a number of locations were rationalised. This involved mine closures at Eneabba and Capel South; closure of RGC's Eneabba dry separation plant; and a reduction in synthetic rutile production from Narngulu near Geraldton (which will be largely offset through increased production from the more efficient plants at Capel).

Successful results from a feasibility study of the Wemen project, near Ouyen in northeast Victoria, are expected to lead to a start in production from this heavy mineral sand deposit in late 2000. In western Victoria, Craton Resources NL announced an inferred resource of 11.3 Mt of heavy mineral concentrates for its Douglas project, near Horsham. BeMax Resources N.L. reported that its Ginkgo deposit in southern New South Wales had an inferred resource of 230 Mt at a grade of 2.6% heavy minerals.

In South Australia, Murray Basin Minerals NL released estimates of the resource base at its Mindarie-Mercunda project – 16.8 Mt grading 3.1% heavy minerals with an indicated resource of 4.1 Mt at 3.4% heavy minerals in the Mercunda section of the project area.

Monto Minerals NL initiated a final feasibility study on its Goondicum Crater ilmenite and titano-magnetite project, 30 km east of Monto, Queensland. The company is evaluating extraction of ilmenite at a rate of about 275 000 tpa for production (by sulphate process) of titanium dioxide pigment.

Nickel

Resources

Total identified resources of nickel rose by 7.7 Mt (29%) in 1999. EDR increased by over 17%, from 9.0 Mt to a record 10.6 Mt, which constitutes about 30% of total identified resources. In Western Australia, Queensland and New South Wales increases in EDR resulted mainly from company reassessments at either existing mines or new deposits nearing production.

Western Australia remains the largest holder of nickel resources with 88% of total EDR. While the measured and indicated categories fell at WMC Ltd's Mt Keith operations, they rose slightly at Kambalda and Leinster. EDR increased significantly at Anaconda Nickel Ltd's Murrin Murrin and the former Abednego laterite deposits. Abednego was acquired by Anaconda Nickel Ltd during 1999 and its resources incorporated into the Murrin Murrin project.

Company reassessment of the Marlborough deposits in Queensland and the Syerston project in New South Wales resulted in slight rises in EDR.

Subeconomic demonstrated resources, which accounted for about 22% of total identified resources, increased by 2.9 Mt during the year. The increase in both paramarginal and submarginal categories was attributable to WMC Ltd's operations at Leinster and Mount Keith, Preston Resources NL's Bulong project, and Anaconda's Pelican and Mount Margaret projects (WA). Falls in both these categories in Queensland and New South Wales followed further drilling and the upgrading of some resources to EDR.

Inferred resources rose by nearly 25% to the record level of 16.1 Mt (following an increase of 28% in 1998). Western Australia accounted for all of the gain, which was associated with the following projects: – Highway (Golden State Resources NL), Goongarrie and Ghost Rocks (Heron Resources NL), Jimberlana and Siberia (Anaconda Nickel Ltd), and Siberia and Siberia Tank (Centaur Mining & Exploration Ltd). Inferred resources in Queensland and New South Wales fell following reclassification of tonnages to higher resource categories.

Exploration

Data relating to exploration for nickel are not available nationally.

Production

In 1999, about 700 kt of nickel concentrates (approximately 126 kt contained nickel) was produced from Western Australia.

World ranking

According to AGSO and the USGS data, world EDR of nickel increased by 4.8% from 45.3 Mt in 1998 to 47.5 Mt in 1999. Australia's share of world EDR rose to 22.3% from 19.8% in 1998, making it the largest holder of EDR, followed by Russia (14%), Canada (13%), and Cuba (12%).

Australia produced about 11% of estimated world nickel output of 1.14 Mt. Russia was again the largest producer with 250 kt (22.7%), followed by Canada with 203 kt (19%) and Australia (11%).

Murrin Murrin nickel processing operation, Western Australia. *(courtesy Anaconda Nickel Ltd)*

Industry Developments

Australia has five nickel sulphide mines currently in operation: WMC Ltd's Kambalda, Leinster and Mount Keith; Outokumpu Oy's Silver Swan, and Titan Resources' Radio Hill. In 1999, three lateritic nickel mines came on stream: Preston Resources' Bulong, Centaur Mining & Exploration's Cawse, and Anaconda Nickel's Murrin Murrin. All these mines are in Western Australia. Australia has one nickel smelter at Kalgoorlie (WA), and two refineries – one at Yabulu (Qld) and the other at Kwinana (WA).

WMC Ltd shut down of its Kalgoorlie Nickel Smelter in early 1999 (to reline the furnace) resulted in a reduction of nickel-in-concentrate production of some 20 kt. As result of continuing low nickel prices, three of its underground mines (Wannaway, Blair and Otter/Juan mines – all within the Kambalda region) were placed on care-and-maintenance.

The Forrestania nickel sulphide mine, in operation for seven years, closed after ore reserves were exhausted. Outokumpu Australia Pty Ltd plans to commence mining at the Cygnet deposit northeast of Kalgoorlie in 2000. Ore from this deposit will be blended with high-grade ore from the adjacent Silver Swan deposit, and nickel-in-concentrate output is to be used as feed for Outokumpu's smelter in Finland.

At Radio Hill in the west Pilbara, Titan Resources NL is evaluating biological oxidization and heap leaching of disseminated copper-nickel-cobalt sulphide mineralisation. The process, owned by Bio-Hydro Metallurgy Ltd of the United Kingdom, maybe suitable for treating mineralization which is currently uneconomic to mine.

In late 1999, Jubilee Mines NL commenced construction work at its proposed Cosmos Nickel Mine. The $37 million project is to be an open-cut operation – extracting 150 ktpa of ore to produce 50 ktpa of nickel concentrate, which will be smelted in Canada.

Each of the new lateritic mines (see above) utilises pressure acid leach, solvent extraction, and electrowinning circuits to process ore. All three companies experienced technical difficulties on commissioning throughout 1999. A summary of the processing technology at each mine is presented in Australia's Identified Mineral Resources, 1999.

Other nickel laterite developments include Anaconda Nickel Ltd's proposed Mount Margaret project and Comet Resources NL's Ravensthorpe project. Mount Margaret's planned annual production is 100 kt of nickel and 5 kt of cobalt. Ravensthorpe is expected to produce 35 kt of nickel-in-concentrate annually. The concentrates will be shipped to Billiton's Yabulu refinery (Qld) for processing to nickel metal.

Other projects at feasibility stage include lateritic deposits at Marlborough in Queensland and Syerston in New South Wales, and sulphide deposits at Maggie Hays and Emily Ann in Western Australia. Billiton Plc is conducting a feasibility study into expanding the capacity (30 to 35 ktpa) of its Yabulu refinery using Ravensthorpe feed.

Phosphate

Australia's commercial resources of phosphate are in Queensland (Phosphate Hill, 150 k south of Mt Isa) and on the Indian Ocean territory of Christmas Island. Phosphate Hill is a world-class rock phosphate resource that is close to surface and easy to access and mine. The rock is ideal for the manufacture of high analysis fertilizers for domestic and international use. The first di-ammonium phosphate (DAP) fertilizer utilising Phosphate Hill ore was produced in late 1999.

Christmas Island is a source of quality rock phosphate, which is exported to the Asia-Pacific and southeast Asian region. Christmas Island rock phosphate products are used widely in the palm oil sector of this region, and sales of higher-grade rock phosphate are made to Australian manufacturers of mono-ammonium phosphate (MAP) fertilizer.

DAP and MAP have different ratios of phosphorous and nitrogen, and have slightly different applications. DAP is used on broad-acre crops such as cereal, legume, fodder, horticultural and row crops, and dairy and newly-established pastures. MAP assists with early crop growth and enhances phosphorous uptake in broad-acre crops.

Resources

EDR of phosphate rock rose by over 20% in 1999 to 107 Mt, all of which is sedimentary phosphate rock (phosphorites), with an average grade of about 23% P_2O_5 at Phosphate Hill.

Most of Australia's demonstrated resources of phosphate occur in the Georgina Basin and are classified as paramarginal. Two deposits, Swan and Emu, occur within carbonatite at Mount Weld, 26 km southeast of Laverton (WA), where a phosphate-rich zone has formed by the solution and weathering of a primary carbonatite.

The bulk of Australia's inferred phosphate resources are in phosphorites in the Georgina Basin, and these are evenly distributed between Queensland and the Northern Territory. A small part of the Mount Weld resource is classified as inferred.

There is no publicly available information on Christmas Island's current phosphate resources.

Exploration

Data relating specifically to exploration for phosphate are not available.

Production

In mainland Australia, less than 5000 t of phosphate rock was mined in 1999 from small deposits in South Australia. This phosphate rock is high in aluminium and iron, and is not suitable for manufacturing superphosphate. It is used as a direct-application fertiliser or for making organic fertiliser for horticultural applications. In 1998-99, Phosphate Resources Ltd (PRL) shipped 700 kt of phosphate rock from Christmas Island.

World ranking

Australia's EDR of phosphate rock comprises less than 1% of the world's total EDR of 12 000 Mt, which occurs principally as sedimentary marine phosphorites.

Industry developments

WMC Fertilizers Pty Ltd (WMCF), a subsidiary of WMC Ltd, continued development of its integrated fertilizer manufacturing facility in Queensland's northwest minerals province. During 1999, the company finished construction and began commissioning facilities at Phosphate Hill, Mount Isa and Townsville. In 2000, it will progressively commission facilities to achieve design capacity and plans to produce more than 700 kt of di-ammonium phosphate.

In the longer term, WMCF is looking to maximise the potential of the Phosphate Hill resource. Its facilities will replace approximately 500 kt of imported fertilizer and export 500 kt to southeast Asia every year.

In 1998-99, PRL reported that its markets in Indonesia returned slowly and that it had developed new markets including New Zealand. In its 1999 Annual Report, the company announced it had been involved in negotiations with the Asia Pacific Space Centre (APSC), a consortia seeking to construct a satellite launching facility at South Point, regarding land that is currently part of PRL's mining lease. PRL's objective is to ensure all reserves of rock phosphate at South Point are mined before transfer of land to APSC.

Shale oil

Shale oil resources and industry developments were not reviewed in 1999. An assessment of resources and review of industry developments will be conducted in 2000.

Tantalum

Increased use of portable electronic devices such as mobile phones, computers and video cameras has maintained strong growth in demand for tantalum capacitors in recent years. Australia, through the operations of Sons of Gwalia Limited, is the world's largest producer of tantalum in the form of tantalum concentrates. The company also controls the world's largest stock of tantalum resources, principally in its holdings at Greenbushes and Wodgina (WA).

Resources

Despite increased production of tantalum pentoxide (Ta_2O_5), EDR increased by 37% in 1999 to just over 24 kt tantalum (Ta). This was largely due to reassessment of resources in the Greenbushes and Wodgina deposits. Sons of Gwalia Limited reported that the resource base at Greenbushes increased from 38.7 to 75.2 million pounds (Mlbs) Ta_2O_5 (17.6 to 34.1 kt Ta_2O_5), while at Wodgina it increased almost sixfold to 31 Mlbs Ta_2O_5 (14.1 kt Ta_2O_5). In assessing EDR for the Greenbushes resources, a recovery factor of 55% (current metallurgical recovery reported by Greenbushes) was applied.

Small levels of resources in the EDR category occur elsewhere in Western Australia and the Northern Territory. The large rise in SDR resulted from reclassification of resources (delineated in 1998) at the Greensbushes deposit. Minor resources in this category occur in New South Wales.

Inferred resources fell by 13% to less than 63 kt Ta in 1999. This followed an upgrading of resources at Mt Cassiterite East by Sons of Gwalia (near its Wodgina mine) in the Pilbara district, and of some resources adjacent to the Greenbushes mine. In central New South Wales, minor resources of native tantalum together with zirconia, rare earths, and niobium are associated with an alkaline intrusive complex.

Exploration

Data relating to exploration for tantalum are not available.

Production

In 1999, Sons of Gwalia produced 741 050 lbs (336 t) of Ta_2O_5 from the Greenbushes operation and a further 187 483 lbs (85 t) from its Wodgina mine.

World ranking

The increase in resources at Greenbushes and Mt Cassiterite East consolidated Australia's position as the world's largest holder of tantalum resources. Based on world estimates published by the USGS and modified by AGSO to take account of recent discoveries, Australia has over 80% of the world's EDR of tantalum. Canada has the second largest resource base, followed by the Congo.

World production in 1999, based on USGS estimates modified to account for later Australian data was over 470 t Ta. Production was dominated by Australia, with 353 t won in 1999 (about 75% of world output). According to the USGS, lesser amounts were produced by Brazil and Canada (60 t each) and Nigeria (3 t).

Industry developments

During 1999, Sons of Gwalia completed commissioning of its processing plant (nameplate capacity 650 ktpa) at Wodgina. The focus is now on optimising metallurgical recovery to achieve maximum productivity from the plant.

As part of its development strategy at Greenbushes, the company embarked on a feasibility study into the potential underground development of the Cornwall ore zone, which cannot be extracted by open-cut mining.

Uranium

Resources

AGSO prepares estimates of Australia's uranium resources within categories defined by the OECD Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA). In Table 1, these estimates are reported under the corresponding resource categories of the national classification scheme. The resource categories of both schemes are correlated as closely as possible in Table 3.

Table 3. Comparison of resource classification schemes for uranium

National 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

During 1999, Australia's low cost RAR (equates to EDR) decreased by 36 000 t uranium (U) to 571 000 t U. This represents a decrease of 6% and was due to the following factors:

- re-calculation of the resources for Olympic Dam by WMC Ltd, resulting in a decrease in the total measured and indicated mineral resources, together with a small decrease in total proved and probable reserves; and
- mine production.

Approximately 95% of Australia's total uranium resources in the low cost RAR category are within the following six deposits:

- Olympic Dam (SA), which is the world's largest uranium deposit,
- Ranger, Jabiluka, Koongarra in the Alligator Rivers region (NT),
- Kintyre and Yeelirrie (WA).

World ranking

Australia has the world's largest resources of uranium in the low cost RAR category, with 26% in this category. Other countries which have significant low cost resources include Kazakhstan (20%), Canada (15%), South Africa (10%), Namibia (7%), Brazil (7%), Russian Federation (6%), and United States (5%) (OECD/NEA & IAEA, 2000).

Exploration

Total expenditure on uranium exploration in Australia for 1999 was $9.25 million, a reduction of over 50% compared to 1998. This significant decline was due to a number of factors including:

- several companies ceasing to explore for uranium in Australia;
- expenditure on the Beverley in situ leach operation no longer attributable to exploration, following commitment in 1999 to develop this project;
- exploration ceasing at the Kintyre project (WA).

The main areas for exploration and deposit types being targeted are:

- Arnhem Land (NT) - unconformity-related deposits in Palaeoproterozoic metasediments below a thick cover of Kombolgie Sandstone,
- Frome Embayment (SA) - sandstone type deposits in Tertiary sediments,
- Paterson Province (WA) - unconformity-related deposits in Palaeoproterozoic metasediments of the Rudall Metamorphic Complex, which hosts the Kintyre orebody,
- Carnarvon Basin (WA) - sandstone type deposits in Mesozoic sediments,
- Mount Isa area (northwest Qld) - exploration continued at the Valhalla deposit.

Production

Uranium oxide was produced at the Ranger and Olympic Dam operations. Australia's total production in 1999 reached a record high of 7055 t U_3O_8 (5983 t U; U=0.848 x U_3O_8), 22% higher than for 1998 with Ranger producing 3857 t and Olympic Dam 3198 t U3O8.

Industry developments

Ranger. Energy Resources of Australia (ERA) Ltd re-assessed the ore reserves for Ranger No. 3 orebody, which further confirmed the viability of extending the open-pit to mine additional ore below the previous mine design. As a consequence, the Ranger No. 3 ore reserves as at 30 June 1999 were revised to 17.1 Mt averaging 0.29% U_3O_8, containing 49,546 t U3O8.

The Ranger mill has capacity to produce between 5000 - 6000 t U3O8 per year, depending on grade and ore type. ERA announced that, from January 1999, mill production would be reduced to a rate of 4000 tpa until the market outlook improves.

Olympic Dam. The Olympic Dam copper-uranium-gold-silver deposit is the world's largest deposit of low-cost uranium. The ore reserves and mineral resources for copper and uranium, as at December 1999 were:

Reserves/Resources		Mt	Cu (%)	U_3O_8 (kg/t)	Contained U_3O_8 t
Reserves	Proved	121	2.4	0.6	72 600
	Probable	485	1.6	0.5	242 500
Resources	Measured	500	1.8	0.5	250 000
	Indicated	1150	1.3	0.4	460 000
	Inferred	670	1.1	0.4	268 000

Note: Measured and indicated mineral resources are inclusive of those mineral resources modified to produce the ore reserves.

The Olympic Dam Expansion project was completed in the first quarter 1999 at a final cost of $1.94 billion. The expansion has increased copper production capacity from 85 000 to 200 000 tpa, with commensurate increases in uranium, gold and silver output. During 1999, 6.743 Mt of ore was milled to produce 3198 t U_3O_8, 84% higher than for the previous year. WMC anticipates that production in 2000 will be approximately 4300 t U_3O_8.

Jabiluka. Construction of the decline (1150 m) and 720 m of underground development to access the Jabiluka orebody were completed by July 1999. On completion, ERA commenced a program of underground diamond drilling, mine planning and further environmental studies.

As part of the environmental impact assessment for the project, ERA investigated two milling options for Jabiluka ore: Ranger Mill Alternative (RMA), ore being transported by truck to the existing Ranger mill for processing; and the Jabiluka Mill Alternative, ore being processed in a mill to be constructed on the Jabiluka lease.

The company's preferred option is the RMA as it will have lesser environmental and social impact in the region. In October, the Northern Land Council, which negotiates on behalf of the Aboriginal Traditional Owners, advised ERA that it would not consider any proposal in relation to trucking ore from the Jabiluka mine to the Ranger mill until at least 1 January 2005. The company subsequently reported that it would now focus on refining the best outcomes that can be delivered by developing a milling operation at Jabiluka.

In July, the World Heritage Committee of UNESCO confirmed that the Jabiluka project would not cause Kakadu's world heritage status to be placed in danger. ERA has agreed to limit Jabiluka production until the Ranger orebody is exhausted. This concession was in response to concerns held by some Committee members that Kakadu would be adversely affected if two mines were in full-scale operation simultaneously. Limited ore processing from Jabiluka is expected to commence in 2001.

Beverley. The environmental impact statement (EIS) for the Beverley in situ leach project was assessed jointly by the Commonwealth and South Australian Governments. The Commonwealth Department of the Environment and Heritage requested AGSO to provide assistance by carrying out a technical assessment of the data provided during the EIS process and to carry out an independent assessment of the hydrology of the Beverley aquifer. AGSO's findings, released in early 1999, showed that the Beverley aquifer is isolated from the Great Artesian Basin aquifer and other surrounding groundwater aquifers. Both the Alpha Mudstone (stratigraphically below the Beverley aquifer sands) and the Beverley Clay (stratigraphically above the Beverley aquifer sands) are thick, highly plastic clays, which are continuous over areas much greater than the extent of the mineralised zone. Both these units provide a high degree of confinement to the mineralised sands. The Beverley aquifer is separated stratigraphically from the Great Artesian Basin aquifer by approximately 100 m of dense plastic clays of the Alpha Mudstone. Pumping tests carried out in 1973 and 1998 also showed that the Beverley aquifer is a bounded, confined aquifer that contains semi-stagnant groundwater.

From the assessment, AGSO concluded that permanent disposal of liquid waste into the Beverley Sand aquifer in the northern mineralised zone at a depth of around 100 m below the surface is the best option for disposal. In this aquifer, the waste will remain isolated from the biosphere throughout time.

In April 1999, Heathgate Resources Pty Ltd received environmental clearances from the Commonwealth and South Australian State Government to develop the Beverley project. Requirements were placed on the company to ensure sound environmental management of the operations.

Development of the project commenced in the latter half of the year. An airstrip, new camp, and access road into the site were completed. Work on the processing plant is also under way as is drilling of the wellfields for in situ leaching.

The project is scheduled to be commissioned in August 2000 with production to commence at a rate of 500 tpa U_3O_8, and increasing to 1000 t in the succeeding few months. Beverley will be Australia's first situ leach operation to mine uranium.

Honeymoon. The Honeymoon deposit, 80 km northwest of Broken Hill, has a roll-front shape and occurs at an oxidation-reduction interface along the lateral margins of a bend in the Yarramba palaeochannel. The deposit occurs within coarse-grained sands of Tertiary age (Eyre Formation) and is between 100 and 120 m below surface.

Aerial view of Honeymoon project, South Australia.
(courtesy Southern Cross Resources (Australia) Pty Ltd)

Impacts of the proposed in situ leach operation are currently being considered under an environmental impact assessment process. A draft EIS for the project is expected to be released by Southern Cross Resources in 2000.

The company is currently updating resource estimates for the Honeymoon, East Kalkaroo and Goulds Dam deposits. The estimates are based on equivalent uranium grades measured by down-hole radiometric probes. To improve the reporting of uranium resources recoverable by in situ leaching, it has recommended changes to the 'Australasian Code for Reporting Mineral Resources and Ore Reserves' (JORC Code) that to include guidelines for reporting resources to be mined by in situ leaching.

Vanadium

Vanadium is used in metal alloys, principally to strengthen steel.

Resources

EDR of vanadium fell by 5% in 1999 due to a reassessment of resources at the Savage River deposit (Tas). The Windimurra deposit (WA) contains more than 95% of Australia's EDR. A number of vanadium deposits in Western Australia and northwest Queensland were evaluated by drilling during the year and the latest resource estimates for these have substantially increased Australia's paramarginal and submarginal demonstrated resources (Table 1).

Vanadium prices have historically shown a high degree of volatility, and in recent years prices have fluctuated over a wide range. In response to strong growth in demand, prices rose rapidly from around US$2 per pound vanadium pentoxide (V_2O_5) in 1994 to a high of US$6.60 per pound in early 1998. These higher prices, together with the successful development of the

Windimurra mine, have generated considerable recent interest in other vanadium deposits in Western Australia. The commercial viability of these projects has also improved through the availability of energy from the Dampier to Bunbury gas pipeline.

Following the high levels of early 1998, prices declined sharply during 1999 to a low of US$1.25 per pound at year end. This decline was attributed to two main factors:

- significant increase in supplies from Russia;
- the Asian crisis, which led to a major reduction in steel and consequently vanadium consumption.

Exploration

There was a significant increase in exploration activities for vanadium during 1998 and 1999. Most exploration has been directed at finding vanadium-titanium deposits within Archaean layered gabbroic intrusions in Western Australia. Exploration for vanadium continued in Cretaceous oil shale horizons near Julia Creek, northwest Queensland.

The Gabanintha-Yarrabubba vanadium project, 45 km southeast of Meekatharra, is currently being evaluated by Greater Pacific Gold NL. Drilling has confirmed the continuity of a magnetite-rich unit to more than 80 m below surface. A combined inferred resource for the Gabanintha-Yarrabubba and Flood Plain portions of the project area is estimated at 62.4 Mt grading 1.13% V_2O_5. An additional inferred resource of 31 Mt grading 0.59% V_2O_5 has been estimated for the hanging-wall zone (Fetherston & Abeysinghe, in prep.). The company is investigating the possibility of developing a mine and processing plant with capacity to produce 5200 tpa V_2O_5.

The Youanmi vanadium project, 120 km east-southeast of Mount Magnet (WA), is being evaluated by Australian Gold Resources (AGR). Vanadium occurs within a thick titano-magnetite layer hosted by a layered gabbroic complex – the Youanmi Intrusive Complex. The Youanmi Complex is similar to the Windimurra Intrusive Complex, 45 km to the northwest, which hosts the Windimurra deposit. An inferred resource of 136 Mt at 0.42% V_2O_5 has been estimated by AGR for Youanmi using a cut-off grade of 0.27% V_2O_5. Preliminary metallurgical testwork shows moderate to high recoveries of vanadium from bulk samples of oxidised and primary ore.

At the Buddadoo prospect, 150 km east of Geraldton (WA), exploration by Australian Gold Resources has confirmed the presence of a vanadium-rich titanomagnetite horizon over a strike length of 3.5 km within a layered gabbroic intrusion. Exploration of this prospect is continuing.

Production

There was no production of vanadium in Australia during 1999. Production of vanadium pentoxide at the Windimurra mine, 75 km southeast of Mount Magnet, commenced in February 2000 (see below).

Industry developments

Windimurra is Australia's only vanadium mining and processing operation. The project is a joint venture between Precious Metals Australia Ltd and a Swiss company, Xstrata AG. The proven ore reserves as at July 1998 were estimated to be 55.4 Mt at 0.497% V2O5.

Vanadium mineralisation is in a magnetite-ilmenite horizon hosted by a layered mafic-ultramafic intrusive body (Windimurra Complex). Vanadium is in the magnetite and ilmenite. The horizon extends for approximately 25 km (Fetherston & Abeysinghe, in prep.).

Mining commenced in July 1999 and by February 2000 approximately 500 kt of ore was on stockpile. The magnetite beneficiation circuit produced 56 800 t of magnetite concentrate averaging 1.18% V_2O_5 during the quarter ended 31 December 1999. Production of vanadium pentoxide from the processing plant commenced in February 2000.

The orebody is mined by conventional open-cut methods and over the first ten years the strip ratio will be a low 0.02:1. As the ore is weathered and friable, mining is essentially free-digging with only minimal requirement for drill and blasting procedures. The open-pit will eventually extend over a strike length of 4 km and to a depth of 40 m.

At full production, it is anticipated that Windimurra will produce 15.8 million pounds (7200 t) of V_2O_5 per year, which represents approximately 12% of world production. Glencore International AG, one of the world's largest natural commodity traders, will market vanadium from the project under a ten-year contract.

The Balla Balla vanadium project in the west Pilbara region, 100 km southwest of Port Hedland (WA), is being evaluated by Renewable Energy Corp. Ltd (formerly Tanganyika Gold NL). The deposit consists of shallow to moderately dipping tabular bodies of titanomagnetite hosted by a gabbroic unit of the Archaean Sherlock intrusion. The single titanomagnetite layer ranges in thickness from 18-34 m and extends for more than 6 km. There are three deposits: - Western, Central and Eastern, which are faulted segments of a single titanomagnetite layer. Weathering has resulted in partial alteration of magnetite to hematite in the upper 15 m. Mineral resources at a cut-off grade of 0.6% V_2O_5 in September 1999 were:

Resources	**Mt**	**% V_2O_5**
Measured	35	0.78
Indicated	34.4	0.78
Inferred	15.1	0.76

A feasibility study to assess the possibility of developing a mine and processing plant was nearing completion at the end 1999. It is proposed to mine approximately 1.2 Mt annually by open-cut methods. Beneficiation by crushing, grinding and magnetic separation would produce approximately 700 kt of vanadiferous magnetite concentrate for roasting with sodium salt to solubilise the vanadium. Roasting will be followed by leaching, hydrometallurgical processing and fusion to produce V_2O_5 flake. Recent investigations indicate that the project will be enhanced by on-site production of high-quality ferrovanadium. As a result, the feasibility study is to be amended to incorporate necessary changes resulting from on-site production of ferrovanadium.

Ferrovanadium usually contains about 80% vanadium, and production is achieved by aluminothermic reduction of a vanadium oxide concentrate. The initial rate of production is planned to be 6000 tpa V_2O_5. Conversion of concentrate to ferrovanadium will produce approximately 3240 t of contained vanadium in ferrovanadium.

The deposit is close to existing infrastructure including a power supply and natural gas pipeline. A comprehensive program of metallurgical test work continued during 1999 with small quantities of high-quality vanadium pentoxide being produced from the tests. An environmental 'Notice of Intent' has been submitted to the Department of Minerals and Energy, Western Australia.

The Balla Balla vanadium project (Don Well - Cain Well deposits) owned by Dominion Mining Ltd adjoins the leases over Renewable Energy's Balla Balla project. Dominion's leases cover the continuation of the titanomagnetite horizon, which hosts the Balla Balla deposit.

The vanadium deposits within Dominion's leases are known as Don Well (Western Zone) and Cain Well (Eastern Zone). Detailed ground magnetic surveys and drilling completed during 1999 established that there is strike continuity of the high-grade mineralisation from Renewable Energy's leases into those of Dominion, and that the ore layer ranges in thickness from 20-35 m.

Total indicated and inferred resources to a vertical depth of 50 m, estimated against a cut-off grade of 0.6% V_2O_5 are:

Zone	Mt	% V_2O_5
Western (Don Well deposit)	17.1	0.72
Eastern (Cain Well deposit)	8.4	0.72

Fimiston Mining NL is investigating the feasibility of recovering vanadium from their Julia Creek oil shale deposits, 15 km east of Julia Creek (northwest Qld). Vanadium occurs in the marine oil shale sediments of the Cretaceous Toolebuc Formation, which outcrops over hundreds of square kilometres in the Julia Creek region.

The Toolebuc Formation is a thin sequence of flat-lying early Cretaceous sediment averaging 15 m in thickness. It is composed of two units: - an upper unit of mixed limestone, oil kerogens and clays; and a lower unit of black calcareous oil shale. The company is investigating the possibility of extracting vanadium from the upper portion of the Formation, where oxidation has enriched the vanadium and rendered the limestone friable and easy to mine and beneficiate.

The total indicated resource at a cut-off grade of 0.2% V_2O_5 is estimated to be 210.5 Mt averaging 0.33% V_2O_5 , and inferred resources of 170 Mt averaging 0.46% V_2O_5. All these resources are less than 15 m below surface.

Zinc, lead, silver

Resources

Australia's total identified resources of zinc (81.5 Mt), lead (51 Mt) and silver (85.4 kt) decreased by 2%, 4% and 6% respectively in 1999. In the same period, EDR of zinc (32 Mt), lead (14.6 Mt) and silver (31.2 kt) decreased by 6%, 15% and 23% respectively as a result of production and reassessment of resources at major mines.

In 1999 Mt Isa Mines' lead-zinc-silver ore reserves and mineral resources (measured and indicated) totalled 15.7 Mt (down 28%) with an additional 2 Mt of inferred resource. Ore reserves were depleted by 3.4 Mt due to mine production and adjustments for mining recovery. Resources upgraded from the measured and indicated categories boosted ore reserves by 2.2 Mt but this and the reclassification of some subeconomic resources resulted in an overall decrease in resources of 5.1Mt.

The Hilton mine's ore reserves and measured and indicated resources remained essentially unchanged at a total of 48.2 Mt, with 14.2 Mt of ore reserves and measured and indicated resources (down 11% from 1998), and an additional 5 Mt of inferred resource. Production at Hilton depleted ore reserves by 0.7 Mt in 1998-99, which was offset by 2 Mt of resource upgraded to reserves from the measured and indicated categories. The inferred resource at George Fisher decreased by 4 Mt to 49 Mt (in 1999) following geological re-interpretation of the peripheral areas of the deposit.

At the McArthur River mine (NT), production depleted ore reserves by 1.2 Mt in 1998-99 but this was offset by improved recovery in the mine and reclassification of resources from the inferred category after diamond drilling. In 1999, measured and indicated resources (including ore reserves) totalled 93 Mt (down 1%) with an additional 8 Mt of inferred resource.

Century mine's measured and indicated resources (including ore reserves) in 1999 totalled 102 Mt, with an additional 2.9 Mt of inferred resource.

At Elura measured and indicated resources (including ore reserves) totalled 22.8Mt (unchanged from 1998) with an additional 8 Mt of inferred resource. A review of mining strategy at depth resulted in a significant increase in ore reserves (2.2Mt) and decrease in overall mineral resources of 1 Mt. Further reductions resulted from production (0.8 Mt in 1998/99) and geotechnical problems (0.3Mt).

Broken Hill's measured and indicated resources (including ore reserves) were 26.9 Mt (down 29%) with an additional 2.1 Mt of inferred resource. Production in 1998-99 totalled 1.9 Mt.

At the Rosebery mine (Tas), a 10% decrease in ore reserves resulted from a 30% increase in cut-off grade, reassessment of remnant resources in previously mined areas, and production (0.7Mt in 1998-99). Continued success with exploration did not fully offset these losses and planned deep exploration drilling was deferred in favour of upgrading existing inferred resources. In 1999, measured and indicated resources (including ore reserves) were 4 Mt (up 1%) with an additional 7.6 Mt of inferred resource.

Deep drilling beneath Gossan Hill and Scuddles mines continued to intersect new mineralisation. Drilling also intersected significant zinc mineralisation at a depth of 550 m in a prospective zone between the Scuddles and Gossan Hill mines.

Exploration

In 1999, Australia's base metals exploration expenditure (including copper, nickel, cobalt) totalled $157.2 million, down 23% compared to 1998.

Production

Mine production in 1999 for zinc, lead and silver was 1.06 Mt, 0.68 Mt, and 1.7 kt respectively. Production was mainly from mines at Cannington, Century, George Fisher, Hilton and Mount Isa in Queensland; McArthur River in the Northern Territory; Broken Hill and Elura in New South Wales; Hellyer and Rosebery in Tasmania; and Scuddles, Gossan Hill and the Lennard Shelf deposits in Western Australia. Australia's gold mines continue to be significant contributors to silver production.

World resources and production

Australia has the world's largest EDR of lead (23%), second largest of zinc (17%) after China, and fourth largest of silver (11%) after Mexico, Canada and the United States. As a producer, Australia ranks first in the world for lead, second for zinc (after Canada) and fourth for silver after Mexico, United States and Peru.

Industry Developments

Mining in the upper zone of the Century orebody commenced during 1999 and the first zinc concentrate was produced late in the year. Ultra-fine grinding of ore to within a range of 7-7.5 microns is an innovative component of the processing plant, which produces concentrates to exacting specifications for zinc, lead, silica and iron content. Concentrate slurry is piped as slurry over 300 km to Kurumba, where it is dewatered and stockpiled ready for shipment to the Budel

smelter in the Netherlands. Permanent power supply for the mine from the Mica Creek power station at Mount Isa came on line in mid-1999.

Commissioning of the George Fisher mine is planned in the second half of 2000. Development of the main haulage tunnel from George Fisher to the nearby Hilton mine and upgrading of facilities at Hilton to load and hoist the ore to surface continued.

Installation of a fine grinding circuit in the lead concentrate production process at the Elura mine yielded a 7% increase in lead recovery to 75%. Fine grinding trials show a similar improvement could be achieved with zinc recovery. Development of the Main Orebody and the Northern Lodes at depth commenced in 1998-99, with mining in this area to underpin production over the next four years.

Century mine open-cut, Queensland.
(courtesy Pasminco, Ltd)

Projection studies at Broken Hill indicate an end-of-mine life by 2006 and planning for a transition to a non-mining local economy is underway. Mining of high grade ore from pillars will contribute to maximising recovery of remaining ore reserves, but mine optimisation studies of historically mined areas has identified 5.1 Mt of resource that is unlikely to be economic to mine. Development of the South Eastern A Lode is planned with ore production to commence in 2000-01.

Mineral industry performance and outlook

The Minerals Council of Australia's annual industry survey (Minerals Industry '99) reported that overall mine production rose by 0.1% in 1998-99, following growth of 5.2% in the previous year. The report noted, however, that Australian mine production has grown strongly over the past ten years, with the Mine Production Index (1992-93 = 100) rising by 55% over this period.

Australian mine production statistics for various commodities in 1999, provided by ABARE, are presented in Table 1. Production of many mineral commodities reached record levels in 1998-99, and overall mine production is projected by ABARE to rise by around 6% in the five years to 2004-05. Substantial growth in mine output over this period is expected for nickel (65%), copper-zinc-lead (4-15%), alumina (13%) and iron ore (16%). Refined copper and zinc production is also forecast to increase in the same period by 29% and 11% respectively (Hogan & Rose 2000). These increases in production reflect increasing output from new operations and expansion in capacity at others, referred to in the preceding commodity assessments. In summary they include:

- increased production of alumina from expanded capacity at the Worsley and Pinjarra refineries;
- the Olympic Dam expansion for copper and achievement of full production at the new Century zinc mine;
- a rise in iron ore production with contributions anticipated from BHP's Orebody 18 and Mining Area C, and Robe River's West Angelas deposit; and
- increasing output from the three new mine-to-metal laterite operations in Western Australia – Murrin Murrin, Cawse and Bulong.

Production and exports of selected mineral commodities for 1998-99 are presented in Table 4. Australia's total minerals and energy export earnings in 1999-2000 are forecast to increase by just under 11% to $43.5 billion (Hogan & Rose 2000). Over the medium term (to 2004-05), however, ABARE forecast reduced export earnings from gold (down 20%), aluminium (down 17%), lead (down 10%) and alumina (down 7%).

New capital expenditure on mining fell by over 20% in 1998-99 to $8.7 billion. While the fall was substantial, the level of expenditure remained historically high, reflecting a significant number of mining projects commissioned in addition to those still under development. From ABS survey data for the December quarter 1999, however, the decline in capital expenditure on mining seems likely to continue in 1999-2000. Based on industry intentions, a fall of almost 35% to $5.7 billion is likely, and should this be realised, real capital expenditure on mining would equate to pre-1992-93 levels.

Table 4. Australian production and exports of selected mineral products 1998-99

Commodity	Production	Exports	Export m$
Aluminium			
Bauxite (Mt)	44.878		141
Alumina (Mt)	13537	10.536	2,888
Aluminium (Mt)	1.589	1.236	2,836
Coal			
Black raw (Mt)	280.17		
Black saleable (Mt)	222.45	163.08	9,557
Brown	65.60		
Copper			
Ores and concentrates (kt)	1,667	1097	822
Refined primary (kt)	284	127	372
Diamond (kc)	43,046	42,483	538
Gold			
Mine production (t)	316.15		
Refined (t) (a)	348.21	427.7	6242
Iron & Steel			
Ore & Pellets (Mt)	159.657	142.208	3,791
Iron and steel (Mt) (b)	16.971	3.347	1,608
Lead			
Ores and concentrates (kt)	838	253	140
Refined (kt)	185	177	180
Bullion (kt)	171	167	173
Manganese			
Ores and concentrates (Mt)	1,647	1,147	157
Mineral sands			
Ilmenite concentrates (kt)	2,352	1,304	139
Rutile concentrates (kt)	242	207	160
Synthetic rutile (kt)	688	501	286
Titanium dioxide pigment (kt)	162	136	346
Zircon concentrates (kt)	427	396	231
Nickel			
Concnetrate (kt)	871		
Refined (kt)	182(c)	151	1,103(d)
Uranium (t U_3O_8)	5,797	6,415	288
Zinc			
Ores and concentrates (kt)	1,947	1,450	581
Refined (kt)	304	198	407

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

(a) Includes gold of Australian and overseas origin

(b) Includes 7.545 Mt pig iron and 8.427 Mt raw steel

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

(d) Sum of all nickel product export values

Source: *Australian Commodity Statistics, ABARE, December 1998*

Mineral Exploration in Australia

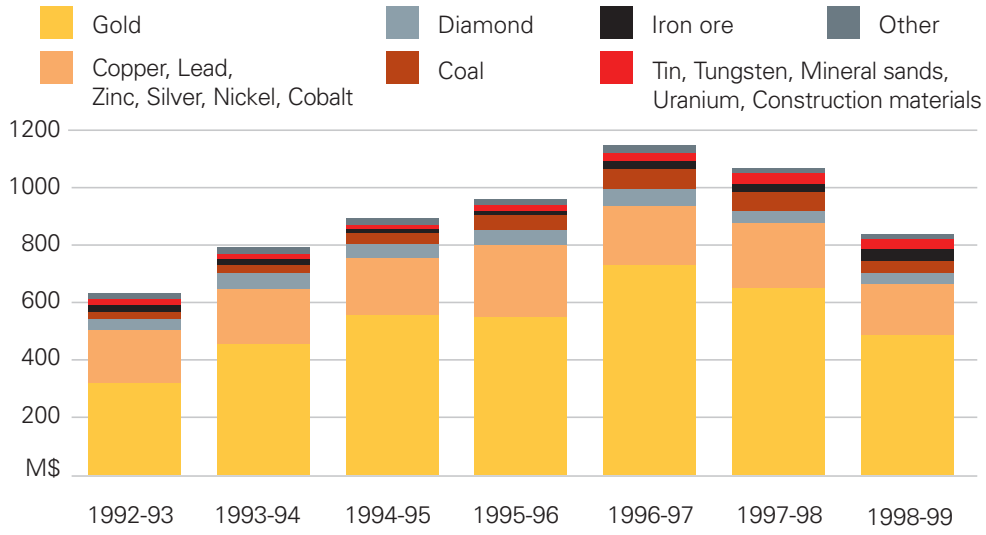
Gamma ray and digital elevation model showing relationship between different soil/regolith types and terrain attributes. *(courtesy John Wilford AGSO)*

Exploration expenditure

Mineral exploration expenditure for a range of mineral commodities is collected by ABS quarterly. The following discussion is based on survey data for 1998-99 (year ending 30 June 1999) and the first two quarters for 1999-2000. The differentiation of commodity groups prior to 1980 is based largely on a breakdown of ABS totals by AGSO.

Australian mineral exploration spending in 1998-99 was $837.8 million. Although still at a relatively high level in current dollar terms (Fig. 2), it was 21.5% ($229 million) less than in the previous year. In actual dollar terms this fall was the largest recorded in the last 30 years and in percentage terms it was the largest since 1983.

Figure 2. Australian mineral exploration expenditure since 1992–93. *Source: ABS*

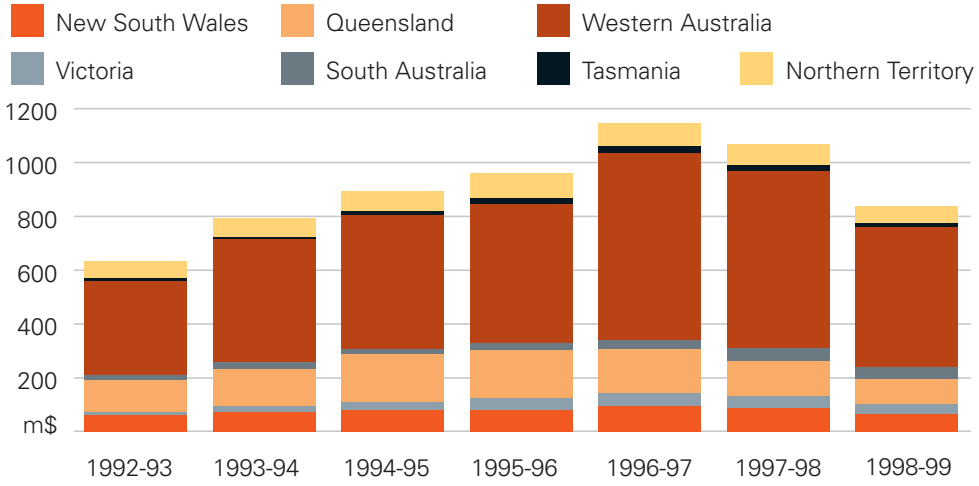


Spending in calendar year 1999, based on the sum of ABS' four quarterly figures, was down by $239 million to $719 million.

While gold remained the principal focus of mineral exploration with 58% of 1998-99 total spending, it suffered a substantial fall (25%) to $486.1 million. Significant falls were also recorded for base metals (down 22%) and coal (down 38%). Following the large growth in uranium exploration expenditure in 1997-98, there was a reduction of 31% in 1998-99 as expenditure fell to $15.4 million. Spending on the search for diamond fell by $1.9 million to $40.9 million. Iron ore, with an increase of 38% to $41.5 million, was the only significant rise in spending recorded.

Exploration expenditure fell in all States and the Northern Territory in 1998-99 (Fig. 3). Western Australia accounted for expenditure of $523.1 million, which was 62.4% of total Australian expenditure. While it maintained its position as the leading State, actual expenditure was down by almost 21% in the year. Queensland retained its position as the second largest State in terms of exploration spending with $93.8 million (11.2% of the Australian total), but this was a reduction of almost 30% over the previous year. Although New South Wales retained its third ranking, spending fell by 25.6% to $65.6 million. The Northern Territory's expenditure fell by 15% to $64.5 million, leaving it only slightly behind New South Wales. A reduction of 6.9% in South Australia resulted in expenditure falling to $41.9 million. Victoria recorded a fall of 14.2% to $37 million and in Tasmania spending fell by 42.5% to $11.9 million.

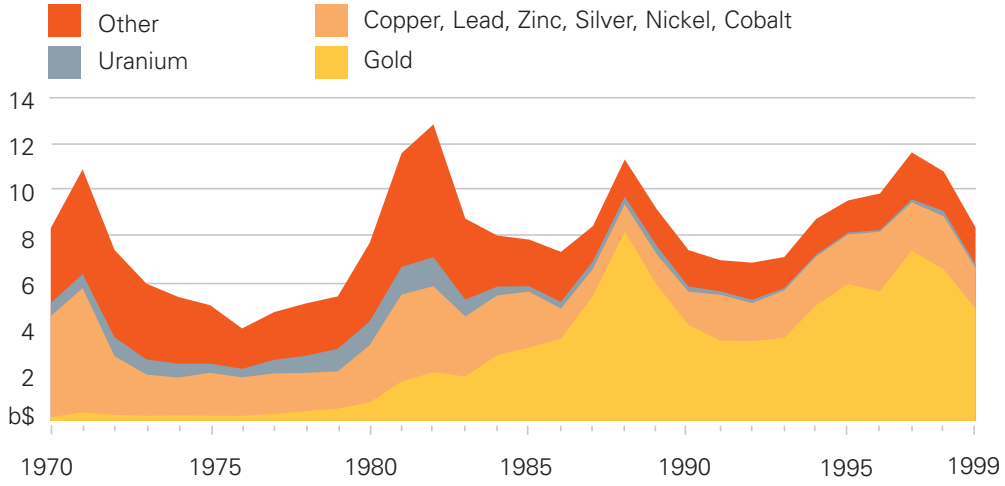
Figure 3. Australian mineral exploration expenditure since 1992-93 by States/NT.



Mineral exploration spending on "production leases" (essentially "brownfields exploration") fell by 21.4% ($54.1 million) in 1998-99. Expenditure in "all other areas" (essentially "greenfields") fell by 21.5% ($174.9 million). Of the total mineral exploration expenditure, 76% or $638.7 million was spent in greenfields areas and $199.1 million in brownfields areas.

In constant 1998-99 dollar terms, spending was at its lowest level since 1993 (Fig. 4). Although this expenditure was substantially down compared with 1997-98, it remains relatively high in historical terms, and was almost $152 million above the low point of the last downturn, which was recorded in 1992.

Figure 4. Australian mineral exploration expenditure since 1969–70 (billion 1998–99 $)



ABS exploration expenditure for the September and December quarters 1999 showed a total decline of 25% ($118.5 million) compared to the equivalent quarters in 1998. Western Australian spending in the period fell by $94.7 million and accounted for most of the overall reduction. Except for South Australia, which fell by $8.3 million, all other jurisdictions fell by less than

$5 million each. Actual expenditures in each State for the six month period are as shown, with the figures for the corresponding quarters of 1998 in brackets: - New South Wales $29.4 million ($32.6 million), Victoria $16.3 million ($20.0 million), Queensland $42.3 million ($47.2 million), South Australia $13.2 million ($21.5 million), Western Australia $216.7 million ($311.4 million), Tasmania $5.0 million ($5.4 million) and the Northern Territory $34.0 million ($37.2 million). Total Australian spending for the six months was $357.0 million.

Outlook for exploration expenditure

ABARE forecast a variable response in exploration spending to changes in commodity prices. Allen and Waring (2000) expect improved spending on exploration for base metals in the next two years. They further expect that expenditure on the search for gold will decline in relative importance as spending on base metals and other minerals increases.

Growing recognition of Australia's high potential for new mineral deposits by overseas companies is likely to have a positive impact on exploration spending. Exploration is likely to be focussed on the major mineral provinces – Yilgarn, Mount Isa, Lachlan Fold Belt, Broken Hill-Olary – and emerging provinces like the Tanami-Arunta and Murray Basin. Much exploration will look for extensions of known mineral districts under shallow cover. These programs will draw on pre-competitive geoscientific data provided by governments; new exploration tools and advanced techniques; the application of sophisticated geological models; and new generation computing capabilities.

Further rationalisation and consolidation in the gold and nickel sectors seems likely, as is an increase in strategic alliances between major international mining houses and junior explorers, which are providing an important stimulus to grass-roots exploration.

Exploration Drilling

AGSO commissioned ABS to undertake a survey of exploration and mining companies to ascertain the amount and type of mineral exploration drilling done in Australia in 1998-99. The survey was commissioned on behalf of ANZMEC's Chief Government Geologists Conference to enable a comparison of expenditure and amount of drilling done throughout Australia for 1998-99. A summary of the survey results was released by ABS on 22 December 1999 in ABS publication 8412.

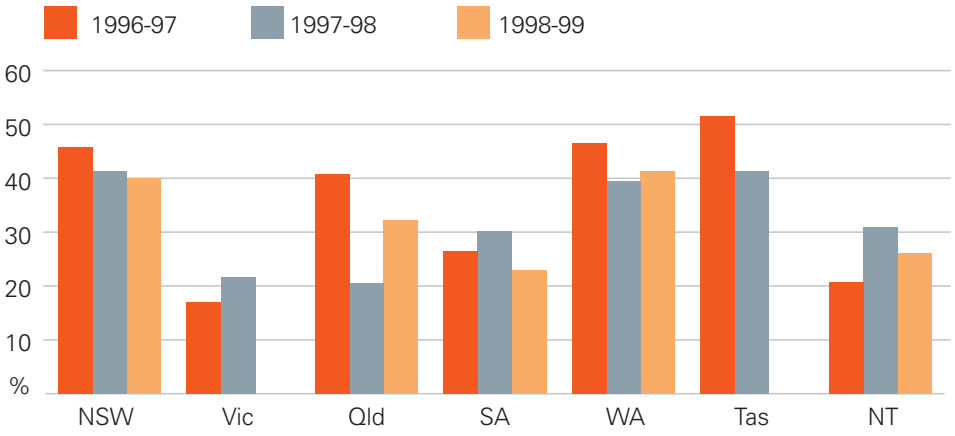
Total Australian spending on exploration drilling in 1998-99 was $313 million, which was a reduction of $65.7 million (17%) compared to the 1997-98 expenditure. The proportion of total exploration spending that was devoted to drilling showed a slight improvement on the previous year, rising from 36% to 37.4%. Although a State-based break down of drilling expenditure is given in Table 5, ABS could not release data for Victoria and Tasmania without breaching its confidentiality rules. Of the jurisdictions for which data were released, Western Australia with 41.4% had the highest proportion of its exploration expenditure going to drilling and South Australia with 23% had the lowest (Fig. 5).

Table 5. Exploration expenditure and exploration drilling, 1998-99

State	Total exploration expenditure ($ million)	Exploration Drilling	
		$ million(a)	'000 metres(a)
New South Wales	65.6	26.236	523.6
Victoria	37.0	n.p.	n.p.
Queensland	93.8	30.219	660.8
South Australia	41.9	9.641	305.2
Western Australia	523.1	216.516	5758.7
Tasmania	26.0	n.p.	n.p.
Northern Territory	64.5	16.854	544
Australia	837.8	313.027	8134.3

Note: Totals and sums of components may vary because of rounding.
(a) Statistics collected by Australian Bureau of Statistics for AGSO, on behalf of the Conference of Chief Government Geologists.
n.p. not made available by ABS for reasons of confideniality

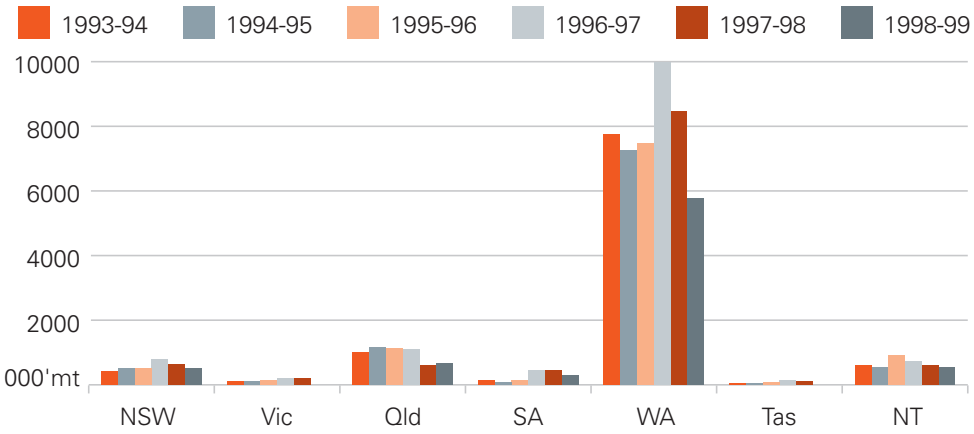
Figure 5. Proportion of Australian mineral exploration expenditure spent on drilling in each State/NT, 1996-97 to 1998-99.



Note: *Data for Victoria and Tasmania for 1998-99 not released by ABS*

In 1998-99, 8.1 million metres of exploration drilling was completed in Australia, a reduction of 26% over the previous year. Of the total metres drilled in 1998-99, 30% was completed in production areas (Table 6), the same proportion as in the previous year. Western Australia was again the leading State for drilling with 5.8 million metres drilled, almost 71% of the total (Figure 6). Although Western Australia was dominant, its share fell from the previous years proportion of 77%. In terms expenditure on drilling, Western Australia spent $216.5 million, 69% of Australian expenditure which was the same proportion as in 1997-98. Queensland had the second highest proportion with 9.7%, followed by New South Wales 8.4%, the Northern Territory 5.4%, and South Australia 3%. The remaining 4.5% was shared by Tasmania and Victoria but,as noted earlier, the results for those States were not released by ABS.

Figure 6. Exploration metres drilled in each State/NT from 1993-94 to 1998-99



Drilling in greenfield areas fell again in 1998-99. A total of just over 5.66 million metres being drilled, 26% less than in the previous year. This was about 70% of all exploration drilling and was unchanged from 1997-98. The total cost of greenfield drilling in 1998-99 was $188.4 million. Despite the depressed state of exploration and the reduced level of drilling undertaken during 1998-99, the average cost of all drilling rose by 12% to $38.48 per metre (Table 6). The rise was due to the increased average cost of diamond and reverse circulation (RC) drilling, which rose by $16.77 and $3.44 per metre respectively. These increases more than offset reductions of $10.10 and $2.51 per metre for percussion and air core/vacuum drilling respectively.

There was a substantial increase in the average cost of diamond drilling in both production areas and other areas. In production areas, the average cost rose by 16.5% to $101.62 per metre and in other areas the increase was 19.6% to $112.86 per metre. RC drilling returned mixed results. In production areas, the average cost of RC drilling rose by 49.4% to $44.69 per metre but in other areas it fell by 7.2% to $36.67 per metre. The other substantial movement in average costs was for percussion drilling. In 1998-99, the average for percussion drilling on production leases fell by 27% to $36.05 per metre and in other areas a fall of 19% to $31.32 per metre was recorded.

Table 7. Active offshore exploration licences in Commonwealth waters

MEL	Granted	Location	Commodity
WA-1	20-Jul-90	120km north of Wyndham, (Ord Prospect)	Diamond
WA-4	10-Mar-92	120km northeast of Wyndham, (Victoria Prospect)	Diamond
WA-7	10-May-94	140km north northwest of Wyndham, (Berkeley Prospect)	Diamond
NT-1	17-Jan-92	170km northeast of Wyndham, (Victoria Prospect)	Diamond
NT-2	17-Jan-92	140km northeast of Wyndham (Victoria Prospect)	Diamond
NT-3	28-Apr-95	300km northeast of Wyndham (Daly River Prospect)	Diamond
NT-4	28-Apr-95	200km northeast of Wyndham (Daly River Prospect)	Diamond
T-2	30-Mar-98	Ringarooma Bay, Tasmania	Tin

Offshore mineral exploration in Commonwealth waters

The Commonwealth Offshore Minerals Act 1994 regulates exploration for and mining of minerals, other than petroleum, over the continental shelf three nautical miles beyond the territorial baselines (generally the low water mark) of the States and Territories.

Applications for a mineral exploration licence (MEL) are made to the Designated Authority (usually the relevant State or Northern Territory Minister responsible for mining) with an application fee of $3,000. The application must be made in the approved manner and must specify details such as:

- block numbers (maximum 500 per application);
- proposed exploration program;
- amount of money allocated to each part of the program;
- technical qualifications of applicant and employees; and
- financial resources.

The initial term of a licence is four years and it may be renewed for three two-year periods subject to the satisfactory performance of licence conditions. There is a mandatory reduction of 50% of the licence area on renewal of a MEL. However, it is possible to apply for an extension of term if activities have been significantly interrupted or stopped by circumstances beyond the control of the licence holder.

As at 29 February 2000, a total of 64 offshore MEL applications had been received since February 1990. Currently there are eight active licences (Table 7). Seven of these are in the Joseph Bonaparte Gulf in the northwest of Australia. This exploration is directed at discovering economic deposits of alluvial diamonds in offshore palaeochannels and tidal shoals. To date no diamonds have been discovered in Commonwealth waters, however, gem quality diamonds have been discovered adjacent to WA-1-MEL and WA-7-MEL in State waters. In Ringarooma Bay tin inferred resource of 23 million cubic metres at a grade of 149 g per cubic metre tin metal was identified by exploration drilling in the 1960's.

Table 6. Exploration drilling in Australia by method and type of area drilled, 1998-99

Drilling method	Production areas			Other areas		
	'000 m	'000 $	Average $/m	'000 m	'000 $	Average $/m
Diamond	642.9	65,33	101.62	583.9	65,89	112.86
Reverse Circulation	863.2	38,57	44.69	1,998.4	73,274	36.67
Percussion	111.0	4,00	36.05	158.7	4,971	31.32
Rotary Air Blast (RAB)	416.5	6,34	15.24	1,720.4	20,71	12.04
Air Core/Vacuum	415.1	9,09	21.92	1,172.9	22,02	18.78
Other	21.5	1,276	59.35	29.8	1,512	50.74
Total	**2,470.2**	**124,63**	**50.45**	**5,664.1**	**188,394**	**33.26**

Drilling method	Total (production and other)		
	'000 m	'000 $	Average $/m
Diamond	1,226.8	131,232	106.97
Reverse Circulation	2,861.7	111,851	39.09
Percussion	269.7	8,973	33.27
Rotary Air Blast (RAB)	2,136.9	27,059	12.66
Air Core/Vacuum	1,588.0	31,124	19.60
Other	51.3	2,788	54.35
Total	**8,134.3**	**313,027**	**38.48**

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Appendix 1

Abbreviations and acronyms

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
ANZMEC	Australian and New Zealand Minerals and Energy Council
BRS	Bureau of Resource Sciences (Bureau of Rural Sciences after 1998)
c	carat
CSIRO	Commonwealth Scientific & Industrial Research Organisation
EAR-1	estimated additional resources - category 1
EDR	economic demonstrated resources
GL	gigalitre
Gt	gigatonne
IAEA	International Atomic Energy Agency
kg	kilogram
km	kilometre
kt	kilotonne
L	litre
m	metre
m3	cubic metre
Mc	million carats
MEL	mineral exploration licence
mm	millimetre
Mt	million tonnes
Mtpa	million tonnes per annum
MW	megawatt
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
SDR	Subeconomic demonstrated resources
t	tonne
Tas.	Tasmania
tpa	tonnes per annum
U	uranium
U_3O_8	uranium oxide
USA	United States of America
USGS	United States Geological Survey
US$	United States of America dollar
Vic.	Victoria
WA	Western Australia

Appendix 2

National classification system for identified mineral resources

Introduction

Australia's mineral resources are an important component of its wealth, and knowledge of the location, quantity and quality of such resources - including estimates of resources yet to be discovered - is an essential prerequisite of formulating sound policies on their use and conservation. Results of resource assessment can be used also to set priorities for mineral exploration and research to indicate mineral potential where alternative land uses are being considered.

In 1975, the then Bureau of Mineral Resources, Geology and Geophysics (BMR) adopted, with minor changes (BMR 1976), the McKelvey resource classification system used by the US Bureau of Mines and USGS (USBM/USGS 1980). Subsequently informal guidelines for using the system's definitions were developed and used by BMR for several years, until the whole system and its application was reviewed in the light of accumulated experience. The results of that review were published (BMR 1984) as the refined BMR mineral resource classification system for national resource assessment.

The principles of the McKelvey system, were retained, as were most of the definitions used by BMR in its original system, although minor changes were made to some. Guidelines on applying the system were established, and adopted. To avoid the confusion arising from use of the term 'reserves', which can have different meaning in other context, notably the JORC Code (1999), it was decided that the term reserves would not be used for regional or national aggregates of resources.

The Bureau of Resource Sciences (BRS) used the modified McKelvey system in preparing its annual national assessments of Australia's identified mineral resources from 1992 to 1998 Following administrative changes in the Australian Government in late 1998, the Mineral and Petroleum Resource Assessment Branches of BRS were incorporated into AGSO within the newly created Commonwealth Department of Industry, Science & Resources. Estimates prepared by BRS and AGSO are therefore consistent with earlier estimates prepared by BMR, which means any analysis of trends is based on consistent datasets.

Several editions of an industry code for reporting resources in individual deposits have been published, the most recent being the 1999 edition entitled "Australasian Code for Reporting Mineral Resources and Ore Reserves", commonly referred to as the JORC code. This was a report of a Joint Committee of the Australasian Institute of Mining and Metallurgy, the Australian Institute of Geoscientists, and the Minerals Council of Australia.

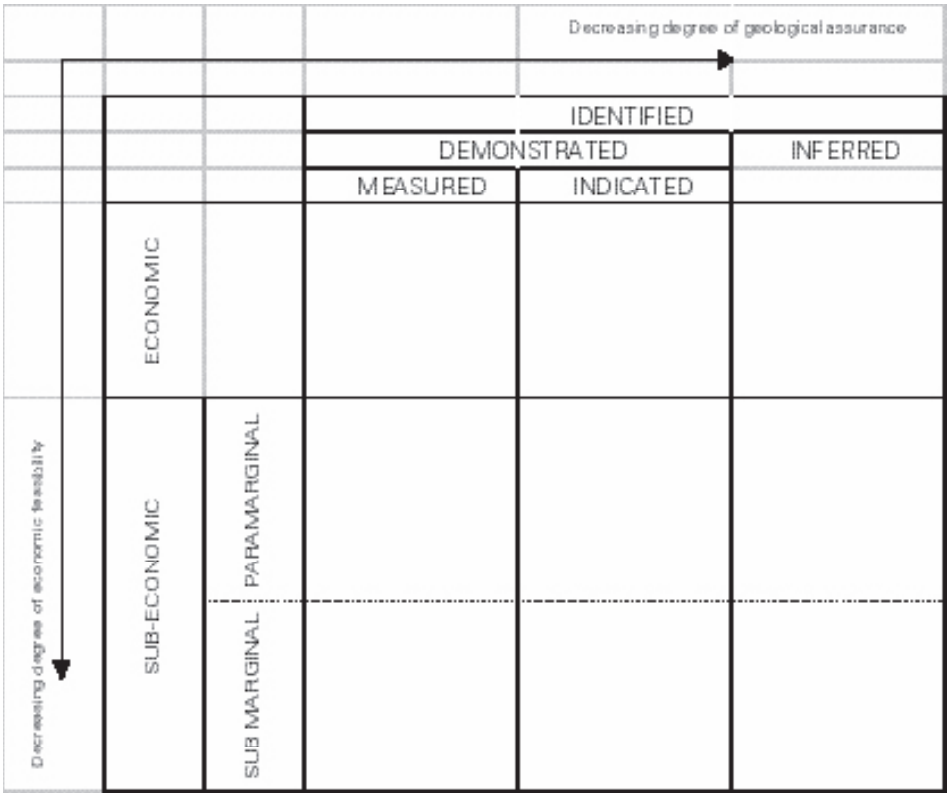
The modified McKelvey system and industry codes are compatible, and data reported for individual deposits under the industry code are used by AGSO in the preparation of its assessments of Australia's mineral resources.

Clasification Principles

AGSO classifies known (identified) mineral resources according to two parameters: degree of assurance of occurrence (degree of geological assurance) and degree of economic feasibility of exploitation. The former takes account of information on quantity (tonnage) and chemical composition (grade); the latter takes account of changing economic factors such as commodity prices, operating costs, capital costs, and discount rates. Resources are classified in accordance with circumstances at the time of classification.

Resources which are not available for development at the time of classification because of legal and/or land-use factors are classified without regard to such factors; however, the amount of resource thus affected will, wherever possible, be stated for each classification category. The classification framework is designed to accommodate all naturally occurring metals, non-metals, and fossil fuels, and to provide a means of comparing data on different resources which may have a similar end use (e.g., petroleum, coal, and uranium as energy sources).

The modified McKelvey system for classifying identified mineral resources is illustrated below.



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 presently or potentially (within a 20-25 year time frame) feasible (see guideline i).

Categories of resources 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 estimates from geological evidence. Identified resources include economic and subeconomic components. To reflect degrees of geological assurance, identified resources can be divided into the following categories:

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.

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

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 for 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 (see guideline ii).

Categories of resources based on economic considerations

ECONOMIC – This term implies that, at the time of determination, profitable extraction or production under defined investment assumptions has been established, analytically demonstrated, or assumed with reasonable certainty (see guideline iii).

SUBECONOMIC – This term refers to those resources which do not meet the criteria of economic; subeconomic resources include paramarginal and submarginal categories.

PARAMARGINAL – That part of subeconomic resources which, at the time of determination, almost satisfies the criteria for economic. The main characteristics of this category are economic uncertainty and/or failure (albeit just) to meet the criteria which define economic. Included are resources which would be producible given postulated changes in economic or technologic factors.

SUBMARGINAL – That part of subeconomic resources that would require a substantially higher commodity price or some major cost-reducing advance in technology, to render them economic.

AGSO guidelines for classifying mineral resources

(i) Use of the term 'resources' is restricted to material, the extraction of which is generally judged to be potentially economically viable in an arbitrary time frame of about 20 to 25 years. The term includes, where appropriate, material such as tailings and slags. The definition does not intend to imply that exploitation of any such material will take place in that time span, but only that its possibility might reasonably be considered. This guideline attempts to establish a lower limit to what is worth assessing. It should be applied on a commodity by commodity basis to take account of prevailing and prospective technologies. Material falling outside the category of resource should be referred to as 'occurrences'. Unless otherwise stated, the classification system refers to in-situ resources. However, it is possible and in fact desirable to also show recoverable quantities of resources in each category.

(ii) By definition, inferred resources are classified as such for want of adequate knowledge and therefore it may not be feasible to differentiate between economic and subeconomic inferred resources. Where inferred resources are shown as 'undifferentiated', the amount known or judged to be economic may be indicated. Such judgements must take careful account of the commodity being assessed and its mode of occurrence as these factors will have a bearing on the reliability of estimates made. Specifically, grade estimates can be more reliably made for concordant sedimentary and biological deposits than for discordant epigenetic deposits (King et al. 1982, p. 8).

(iii) The definition of 'economic' is based on the important assumption that markets exist for the commodity concerned. All deposits which are judged to be exploitable economically at the time of assessment, whether or not exploitation is commercially practical, are included in the economic resources category. It is also assumed that producers or potential producers will receive the 'going market price' for their production. The classification is therefore based on the concept of what is judged to be economic rather than what is considered to be commercial at any particular time.

The information required to make detailed assessments of economic viability of a particular deposit is commercially sensitive (e.g., a company's costs and required internal rate of return), and these data may not be available to organisations such as AGSO. Furthermore, as corporate strategies are likely to be different, individual companies will have different criteria for what is considered to be 'economic'. Thus to standardise the approach for national or regional resource assessments, the following mineral deposits/situations are accepted by AGSO, as a general guide, to be economic:

(a) the resources (published or unpublished) of operating enterprises, whether or not such operations are sustained by long- or short-term, direct or indirect, government subsidies;

(b) resources in a deposit which is being developed for production (i.e., where there is a corporate commitment to production);

(c) undeveloped resources which are judged to be economic on the basis of a financial analysis using actual, estimated, or assumed variables – viz., the tax rate, capital and operating costs, discount rate (such as reflects the long-term bond rate), commodity prices, and depreciation schedules; the values for the economic variables used in an assessment must be realistic for the circumstances prevailing at the time of the assessment;

(d) resources at mines on care-and-maintenance meeting the criteria outlines in (c) above.

(iv) The term 'recoverable' is considered to make allowance for mining as well as processing losses. Where a finer distinction needs to be made, mineable is used to take account of mining losses and metallurgically recoverable (saleable for coal) is used to take account of processing losses.

(v) Some minerals derive their economic viability from their co-product or by-product relationships with other minerals. Such relationships and assumptions must be clearly explained in footnotes or in accompanying text.

(vi) National aggregates of resource estimates should be rounded to the appropriate last significant digit, so as not to create false impressions of accuracy.

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Appendix 3

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List of Plates

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AUSTRALIA'S MINES AND MAJOR MINERAL DEPOSITS

SCALE 1:10 000 000

0 100 200 300 400 500

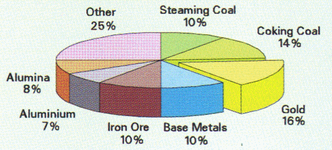
KILOMETRES

LAMBERT CONFORMAL CONIC PROJECTION
Central Meridian : 134 °E Standard Parallels : 18 °S, 36°S
Geocentric Datum of Australia

MINERALS COUNCIL OF AUSTRALIA

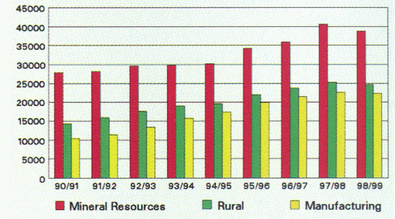
AGSO AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

The Composition of Australian Mineral Exports 1998/99



Source: Australian Commodities, December 1999 (ABARE)

Australia's Major Export Earnings (A$ millions)



- *Operating mine*
- *Undeveloped deposit*
- *Oil and gas fields*
- *Coal producing areas*
- *Oil refinery*
- *Export port for mineral commodities*
- *Power station (> 300 megawatts)*

COMMODITIES

Ag	Silver	Nb	Niobium
Au	Gold	Ni	Nickel
Ba	Barium	Opal	Opal
Bx	Bauxite	Osh	Oil shale
Clay	Clay	P	Phosphorus
Co	Cobalt	Pb	Lead
Coal	Coal	Pd	Palladium
Cr	Chromium	PGE	Platinum Group Elements
Cu	Copper	Pt	Platinum
Dia	Diamond	REE	Rare Earth Elements
Fe	Iron	Rut	Rutile
Fluo	Fluorite	Salt	Salt
Ga	Gallium	Sapr	Sapphire
Gems	Gemstone	Sb	Antimony
Gyps	Gypsum	Sc	Scandium
Hf	Hafnium	Sil	Silica
HM	Heavy minerals	Sn	Tin
Ilm	Ilmenite	Ta	Tantalum
In	Indium	Talc	Talc
Jade	Jade	Ti	Titanium
Kaol	Kaolin	U	Uranium
Kyan	Kyanite	V	Vanadium
Li	Lithium	Verm	Vermiculite
Mags	Magnesite	W	Tungsten
Mica	Mica	Y	Yttrium
Mn	Manganese	Zn	Zinc
Mnsd	Mineral sands	Zr	Zirconium
Mo	Molybdenum	Zrcn	Zircon
Mona	Monazite		

MAIN MINERALISED REGIONS BY PREDOMINANT AGE

- *Mainly Phanerozoic basin cover*
- *Palaeozoic to Mesozoic*
- *Palaeozoic (545-250 million years old)*
- *Proterozoic to Palaeozoic*
- *Proterozoic (2500-545 million years old)*
- *Archaean to Proterozoic*
- *Archaean (> 2500 million years old)*

APRIL 2000 (SECOND EDITION)

AGSO

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION