



Australian Government
Geoscience Australia

AUSTRALIA'S IDENTIFIED MINERAL RESOURCES 2004



Australian Government Geoscience Australia

Industry, Tourism and Resources Portfolio

Minister for Industry, Tourism and Resources: The Hon. Ian Macfarlane, MP

Parliamentary Secretary: The Hon. Warren Entsch, MP

Geoscience Australia*

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ISSN 1327-1466

Bibliographic reference: Geoscience Australia 2004. Australia's Identified Mineral Resources 2004. Geoscience Australia, Canberra.

* Geoscience Australia grew out of the Bureau of Mineral Resources (BMR) and the Division of National Mapping, both of which were founded soon after World War 2. BMR became the Australian Geological Survey Organisation (AGSO) in 1992, several years after the Division of National Mapping had become the Australian Surveying and Land Information Group (AUSLIG). In 2001, AGSO and AUSLIG merged to become Geoscience Australia, the nation's geoscience research and information agency. Further information is available at www.ga.gov.au.

FRONT COVER: Reclaiming Marra Mamba iron ore from stockpiles at Mining Area C, Pilbara Region of Western Australia (BHP Billiton Iron Ore).

DESIGN AND LAYOUT: Lindy Gratton, Geospatial Applications and Visualisation (GAV), Geoscience Australia

Foreword

Geoscience Australia provides information on the nation's future capacity to produce mineral resources. *Australia's Identified Mineral Resources* is an annual nation-wide assessment of Australia's ore reserves and mineral resources. All major and a number of minor mineral commodities mined in Australia are assessed. It includes evaluations of long-term trends in mineral resources, international rankings, summaries of significant exploration results, brief reviews of mining industry developments, and an analysis of mineral exploration expenditure across Australia. Comparable information on petroleum resources is published in another Geoscience Australia publication: *Oil and Gas Resources of Australia*.

Australia's Identified Mineral Resources provides technical information on mineral and energy resources, which is used in formulating Government policies and reproduced by the Australian Bureau of Statistics. It also provides government, industry, the investment sector and general community with an informed understanding of Australia's known mineral endowment and level of exploration activity.

To meet the increasing demand from Asian steel mills, particularly in China and Japan, Australian mining companies have initiated major expansions in mine production of coking coal, iron ore and manganese ore. *Australia's Identified Mineral Resources* provides government with the information required to monitor whether such resources are being discovered and developed for production at rates sufficient to maintain Australia's position as a major supplier to international markets. For this reason, resource assessment for the national inventory takes a long term view of what is potentially economic. Data on mining company estimates of ore reserve (JORC Code), which are generally based on short to medium term commercial considerations, are also included for comparison.

National assessments of this type are assuming greater significance given international trends in the minerals industry. Take-overs and mergers amongst the larger companies in recent years have led to consolidation of the minerals industry. These companies explore or acquire mineral resources in a global context, seeking opportunities for large and high grade deposits that can be mined cost-effectively with low impacts and low risks. There has also been a decline in the number of medium sized mining companies, which have traditionally been very active and successful in Australia.

Resources data from *Australia's Identified Mineral Resources* have also been included in an online atlas of Australia's Mineral Resources, Mines and Processing Centres, developed by Geoscience Australia with support from the Minerals Council of Australia and Department of Industry, Tourism and Resources, through the Government's Regional Minerals Program. The atlas, which can be viewed at www.australianminesatlas.gov.au, has a web-based GIS (geographic information system) format and shows the location of mineral and energy resources, mines and production/processing centres.



NEIL WILLIAMS

Chief Executive Officer
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Summary

Australia's economic demonstrated resources (EDR) of the following mineral commodities increased during 2003 – bauxite, copper, diamonds (both gem and industrial), ilmenite, lead, nickel, niobium, silver, tantalum, tin, zinc and zircon. EDR of black coal, iron ore, lithium, magnesite, manganese, platinum group metals, rare earth elements, rutile and uranium decreased during the year. EDR for brown coal, cobalt, gold, molybdenum, phosphate rock, shale oil, tungsten and vanadium remained at levels similar to those reported in 2002.

Increases in EDR were due to on-going drilling and evaluation of known deposits resulting in the transfer (re-assessment) of resources from inferred or sub-economic categories into EDR, and discoveries of new deposits or extensions of known deposits. The large increase in EDR for copper during the year resulted from a re-assessment of measured and indicated resources for Olympic Dam deposit (SA), and the discovery of additional economic resources at Mount Isa and Ernest Henry deposits (Qld).

Decreases in EDR of black coal and iron ore during 2003 reflect increased rates of mine production. In addition, mining companies re-estimated their ore reserves and mineral resources more conservatively so as to comply with the requirements of the *Australasian Code for Reporting of Mineral Resources and Ore Reserves* (JORC Code).

World ranking: Australia's EDR of zinc, lead, nickel, mineral sands (ilmenite, rutile, zircon), tantalum and uranium remain the world's largest, while bauxite, black coal, brown coal, copper, gold, iron ore, lithium, manganese ore, niobium, silver and industrial diamond rank in the top six worldwide.

Accessible economic demonstrated resources (AEDR): A relatively small number of mineral deposits are currently inaccessible for mining because of government policies, or environmental and land-use restrictions that prevent mining. In particular, this is the case for some mineral sands and uranium deposits.

Resources and current rates of mine production: Ratios of AEDR to current mine production provide rough estimates for the resource life. These indicate that AEDR of most major commodities can sustain current rates of mine production for many decades.

The resource lives for gold (just under 20 years at current rates of production), lead (less than 30 years) and zinc (less than 25 years) are amongst the lowest. There is a need for ongoing successful exploration in the short and medium terms to maintain gold as one of Australia's main export commodities. Similarly, new discoveries of large lead and zinc deposits are needed in the not too distant future to sustain production of these commodities at current levels, given that almost all existing base metal mines will have closed, and also that there is typically a period of 10 years between initial discovery of a deposit and commencement of production for large base metal mines.

Mineral exploration: Mineral exploration expenditures in Australia rose by \$75 million to \$732.6 million in 2002–03. Spending for calendar year 2003 rose by just over \$57 million to \$735.3 million. These modest rises follow a decrease of 51% (from \$1340.26 to \$657.60 million) during the period 1996–97 to 2001–02.

Gold was again the principal commodity sought and its share of total exploration remained steady at 51.7% in 2002–03. While retaining its dominant position, exploration expenditure on gold rose by \$47.1 million to \$378.4 million, its highest level since 1998–99.

Exploration spending on coal and iron ore increased substantially in 2002–03. Coal exploration rose by almost 55% to \$77.9 million, surpassing the previous high of \$70.5 million recorded in 1996–97. Iron ore exploration spending increased by 76.6% to \$44.5 million which was the highest expenditure reported in the last decade.

In response to nickel prices and export earnings, which have increased progressively since mid-2002, spending on exploration for nickel-cobalt in Australia rose by almost 23% to \$65.9 million in 2002–03. Zinc-lead-silver exploration expenditure of \$36.6 million was \$1.0 million less than in 2001–02.

A world survey of exploration budgets for 2003 by the Metals Economics Group showed a worrying trend – Australia's share of global exploration expenditure continued to fall, decreasing to 15.5% from 17.6% in 2002, while Canada was again the leading country with 21.5% of world budgets. The decreases in mineral exploration expenditure in Australia over the period 1996–97 to 2001–02, and the following increase, broadly reflect global trends. However, most other mining countries experienced less significant falls in exploration and a more significant rebound in this period. If this trend is sustained, Australia's mineral production and exports will decline over the medium to long-term.

To address the decline in exploration, the Minister for Industry, Tourism and Resources, the Hon. Ian Macfarlane, MP, announced the *Mineral Exploration Action Agenda* on 12 September 2002. A Strategic Leaders Group made up of industry and government representatives was formed to identify the priority issues impacting exploration investment in Australia, and possible solutions.

The group made 12 recommendations to address issues that it considered critical to the viability of the mineral exploration industry and the long-term sustainability of the mineral resources sector. These recommendations, which were presented in July 2003 in *Mineral Exploration in Australia*, were to:

1. Develop regional template agreements to resolve native title and heritage issues;
2. Encourage use of the expedited procedure in the *Native Title Act 1993*;
3. Amend the *Aboriginal Land Rights (NT) Act 1976* to facilitate the decision-making process;
4. Develop a coordinated national approach to resolve impediments to land access;
5. Introduce a flow-through share scheme;
6. Introduce a general tax deduction uplift factor for greenfields exploration expenditure;
7. Implement the full deductibility of all costs associated with Native Title requirements;
8. Undertake a major pre-competitive geoscience survey program to achieve national coverage to modern standards of basic geoscience datasets;
9. Develop nation-wide protocols, standards and systems for internet-based access to all exploration related data;
10. Launch a '50 early-career explorer' scheme for new graduates and holders of doctorates;
11. Increase higher education funding for geoscience; and
12. Establish a deep ore discovery research and development program.

Introduction

Geoscience Australia (and its predecessors) has prepared annual assessments of Australia's mineral resources since 1975. The resource data and related information from *Australia's Identified Mineral Resources* are used by the Australian Bureau of Statistics, and provide input into Government policy decisions relating to the minerals sector and sustainable development of mineral resources. Data on Australia's resources of coal and other energy minerals were used in preparation of the Government's White Paper on energy entitled *'Securing Australia's Energy Future'*, which was released in June 2004.

In *Australia's Identified Mineral Resources 2004*, estimates of Australia's mineral resources of all major and several minor mineral commodities are reported for 2003 (Table 1). The estimates are based on published and unpublished data available to Geoscience Australia up to the end of December 2003. These resource estimates are compared with national totals of ore reserves for these commodities, as collated by Geoscience Australia from company reports. Mine production data are based on ABARE figures. World ranking of Australia's mineral resources have been calculated mainly from information in publications of the United States Geological Survey (USGS). A summary of significant industry developments is also presented.

Australia's Identified Mineral Resources 2004 also provides information and analysis on mineral exploration expenditures in Australia for 2002–03, and puts these into perspective by comparisons with exploration expenditures (in real terms) over the preceding 32 years.

The mineral resource classification scheme used for Australia's national inventory is based on two general criteria: i) the geological certainty of existence of the mineral resource, and ii) the economic feasibility of its extraction over the long term (see Appendix 2 'National classification system for identified mineral resources'). The classification category, economic demonstrated resources (EDR), is used instead of 'reserves' for national totals of economic resources. This is because the term 'reserves' has a specific meaning for individual mineral deposits under the criteria of the *Australasian Code for Reporting of Mineral Resources and Ore Reserves* (known as the JORC Code) used by industry for reporting ore reserves and mineral resources. EDR provide a basis for meaningful comparisons of Australia's economic resources with those of other nations. Ore is generally mined from resources in the EDR category.

Geoscience Australia has estimated the amount of resources within EDR that are currently accessible for development and mining. Some mineral deposits are currently inaccessible for mining because of Government policies, or various environmental and land-use restrictions that prevent mining such as: location within National/State parks and conservation zones, environmental protection issues, and location within military training areas. Accessible economic demonstrated resources (AEDR) as shown in Table 1 represent the resources within EDR that are currently accessible for mining. It should be noted that the factors which restrict access for mining could change or be abolished in future years.

As the national ore reserves (OR) figures included in Table 1 are from estimates prepared by companies for mine planning and marketing purposes, they generally have a shorter term outlook than EDR.

Long-term trends in EDR for bauxite, black coal, iron ore, gold, copper, nickel, lead, zinc, mineral sands and uranium are presented and the reasons for significant changes in resource trends are discussed.

EDR/production, AEDR/production and OR/production ratios provide information on the resource life of Australia's mineral commodities based on production rates at the time of assessment. Each of these has deficiencies as an indicator of resource life: OR/production is a more conservative (and for some commodities very much more conservative) indicator than EDR/production. The ratios can change quite rapidly, for example as a result of major changes in production rates, changes in metal prices, and other factors.

TABLE 1. Australia's resources of major minerals and world figures as at December 2003.

COMMODITY	UNITS	AUSTRALIA						WORLD		
		Demonstrated Resources			Inferred Resources (a)	Accessible EDR(b) (AEDR)	JORC Reserves(c) (% of AEDR)	Mine Production(d) 2003	Economic Demonstrated Resources(e)	Mine Production(f) 2003
		Economic (EDR)	Subeconomic							
	Para-marginal		Sub-marginal							
Antimony	kt Sb	85	31	51	56	85	50.8 (60%)	–	1800	142
Asbestos Chrysotile ore	kt	–	46.2	–	75	–	–	–	large	2.1 ^(g)
	Crocidolite fibre	–	0.4	–	2	–	–	–	large	
Bauxite	Gt	5.5	0.4	1.7	0.6	5.2	2.1 (40%)	0.056	23	0.14 ^(e)
Black coal in situ recoverable	Gt	54.6	8.1	12.7	84.7					
	Gt	38.3	4.6	9.3	52.3	38.2	14.2 ^(h) (37%)	0.358 ⁽ⁱ⁾	776 ^(j)	3.9 ^{(j)(k)}
Brown coal in situ recoverable	Gt	41.7	43.4	18.1	112					
	Gt	37.5	39.0	16.3	100.8	30.0	2.1 ^(h) (7%)	0.068	186 ^(j)	0.9 ^(j)
Cadmium	kt Cd	84.4	8.5	23.8	22.5	84.4	68 (81%)	0.38	579	15.0
Cobalt	kt Co	1449	164	169	1169	1449	571 (39%)	5.12	6949	46.9
Copper	Mt Cu	40.1	3.1	1.2	22.1	40.1	20.1 (50%)	0.829	490	13.9
Diamond gem & near gem industrial	Mc	72.2	201.4	0.2	20.8	72.2	71.1 (98%)	15.2	–	75.8
	Mc	75.1	209.6	0.3	21.6	75.1	74 (99%)	15.8	580	65.5
Fluorine	Mt F	–	0.2	23.4	18.7	–	–	–	112 ^(l)	2.2 ^(m)
Gold	t Au	5382	1437	107	2933	5370	3432 (64%)	282	43000	2619
Iron ore	Gt	12.4	1.2	1.9	16.7	12.4	4.3 (35%)	0.213	143.0	1.14
Lead	Mt Pb	19.3	1.9	9.2	24.9	19.3	10.5 (54%)	0.688	71	2.8
Lithium	kt Li	167	54	26	7	167	145 (87%)	3.5	4107	14.5 ^(m)
Magnesite	Mt MgCO ₃	344	22	35	931	344	37 (11%)	0.473 ⁽ⁿ⁾	7629	11.6
Manganese ore	Mt	124.0	23.1	167.0	197.3	124.0	89 (72%)	2.55	967.0	21.0
Mineral sands Ilmenite Rutile Zircon	Mt	208.8	51	0.1	107	172.4	40.1 (23%)	2.01	627	8.11
	Mt	21.3	12	0.1	25	15.6	3.2 (21%)	0.173	49	0.42 ^(m)
	Mt	32.2	19	0.2	26	24.0	5.1 (21%)	0.462	77	0.89
Molybdenum	kt Mo	0.4	6.3	3.7	411	0.4	0	–	8600	127
Nickel	Mt Ni	22.8	2.3	1.6	16.4	22.8	7 (31%)	0.192	62.8	1.4
Niobium	kt Nb	194	115	0	1838	194	21 (11%)	^(o)	4604	29.8
Phosphate rock	Mt	91	981	–	1126	9	91 (100%)	0.922 ^(p)	18000	138
								0.586 ^(q)		
PGM (Pt,Pd,Os,Ir,Ru,Rh)	t metal	18.5	153.9	5.4	64.4	14.2	0.1 (1%)	0.61	71000	358 ^(r)
Rare earths (REO & Y ₂ O ₃)	Mt	0.2	2.3	11.6	7	0.1	0 (–)	–	89	0.10
Shale oil	GL	4.6	202	3719	41425	4.6	4.6 (100%)	0.1	95885 ^(s)	0.47 ^(t)
Silver	kt Ag	42.9	9.8	11.8	42.7	42.9	26.8 (62%)	1.868	284	18.8
Tantalum	kt Ta	41	34	0.2	78	41	40.3 (98%)	1.02 ^(u)	43.6	1.24
Tin	kt Sn	146	103	135	317	146	129 (88%)	3.818	6100	265
Tungsten	kt W	8.6	31.8	27.6	56.7	8.6	0 (–)	0	2900	59.5
Uranium	kt U	675	14	33	332	601	435 (72%)	7.57	1716 ^(v)	35.84 ^(w)
Vanadium	kt V	0	779	1807	2475	0	0 (–)	0.389	13000	60
Zinc	Mt Zn	34.8	6.3	16.0	31.8	34.9	22.6 (65%)	1.479	222	8.3

See notes on following page.

Notes for Table 1

Abbreviations: t = tonne; m³ = cubic metre; L = litre; kt = 10³t; Mc = 10⁶ carat; Mt = 10⁶t; Gt = 10⁹t; GL = 10⁹L.

- (a) Total inferred resources in economic, sub-economic and undifferentiated categories.
- (b) Accessible EDR (AEDR) is the portion of total EDR that is accessible for mining. AEDR does not include resources which are inaccessible for mining because of environmental restrictions, government policies or military lands.
- (c) Joint Ore Reserves Committee (JORC) Proven and Probable Ore Reserves as stated in company annual reports and reports to Australian Stock Exchange.
- (d) Sources: Australian Bureau of Agricultural and Resource Economics (ABARE); WA Dept of Industry and Resources – Western Australian Mineral Statistics Digest 2003.
- (e) Sources: Geoscience Australia for Australian figures, USGS Mineral Commodities Summaries for other countries.
- (f) World mine production for 2003, mostly USGS estimates.
- (g) Includes chrysotile production.
- (h) Black and brown coal reserves include both JORC reserves and Geoscience Australia estimated reserves for operating mines that do not publish JORC reserves.
- (i) Raw coal.
- (j) Geoscience Australia estimate.
- (k) Saleable coal.
- (l) Excludes Morocco and USA.
- (m) Excludes USA.
- (n) Magnesite MgCO₃.
- (o) Not reported by mining companies.
- (p) Source: WMC Resources Ltd 2003 Annual Report (di-ammonium phosphate 759 856 t; mono-ammonium phosphate 162 121 t).
- (q) Source: Phosphate Resources Ltd Annual Report 2003 (518 500 dry tonnes of rock shipped; 67 237 dry tonnes of dust shipped).
- (r) Platinum and palladium only.
- (s) WEC Survey of Energy Resources for 1999.
- (t) WEC Survey of Energy Resources for end-2002.
- (u) Ta₂O₅.
- (v) Source: OECD/NEA & IAEA (2004). Compiled from the most recent data for resources recoverable at <US\$40/kg U. Data for USA is not available for this category.
- (w) Source: World Nuclear Association.

Trends in Australia's Economic Demonstrated Resources of Major Mineral Commodities

The trends in EDR for Australia's major mineral commodities have undergone significant and sometimes dramatic changes over the period 1975 – 2003 (Fig. 1). These changes for each commodity can be attributed to one, or a combination of the following factors:

- increases in resources resulting from discoveries of new deposits, and delineation of extensions of known deposits,
- depletion due to mine production,
- fluctuations in commodity prices and currency exchange rates which can move previously subeconomic resources into EDR,
- advances in mining and metallurgical technologies, eg. carbon-based processing technologies for gold have enabled economic extraction of gold from low-grade deposits, which were previously uneconomic,
- adoption of a new resource classification scheme (JORC Code) by the Australian minerals industry and the subsequent impacts on re-estimation of ore reserves and mineral resources so as to comply with the requirements of the Code. In 1988, the Australian mineral industry adopted the *Australasian Code for Reporting of Identified Mineral Resources and Ore Reserves* (JORC Code). Many companies first used this code for reporting their mineral resources in 1989. The requirements of the Code differed significantly from the resource classification schemes used by companies prior to 1989. This led to a re-estimation of mineral resources by many companies to comply with the Code, and some re-assessments of resource data for other deposits by the former Bureau of Mineral Resources. The impacts of the Code on EDR occurred at differing times for each of the major commodities.

Past trends and changes in EDR for a number of Australia's major mineral commodities are discussed below. It is notable that resources levels for a number of major commodities have plateaued.

BLACK COAL

A major re-assessment of NSW coal resources during 1986 by the NSW Department of Mineral Resources and the Joint Coal Board resulted in a large increase in black coal EDR as reported in 1987 (refer 'a' on Fig. 1).

EDR for black coal has declined since 1998 due to the combined impacts of mining companies re-estimating ore reserves and mineral resources more conservatively so as to comply with requirements of the JORC Code, and increased rates of mine production.

BAUXITE

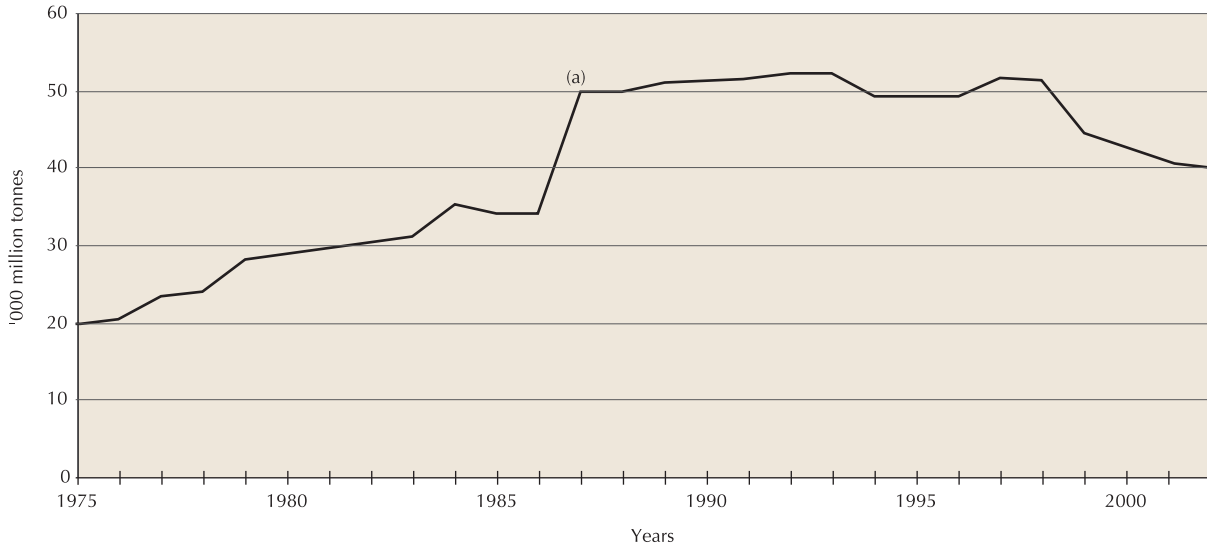
Increases in bauxite EDR in 1989 resulted from delineation of additional resources in deposits on Cape York Peninsula ('b' on Fig. 1). Decreases in bauxite EDR in 1992 were due to re-classification of some resources within deposits on Cape York Peninsula so as to comply with requirements for the JORC Code ('c').

IRON ORE

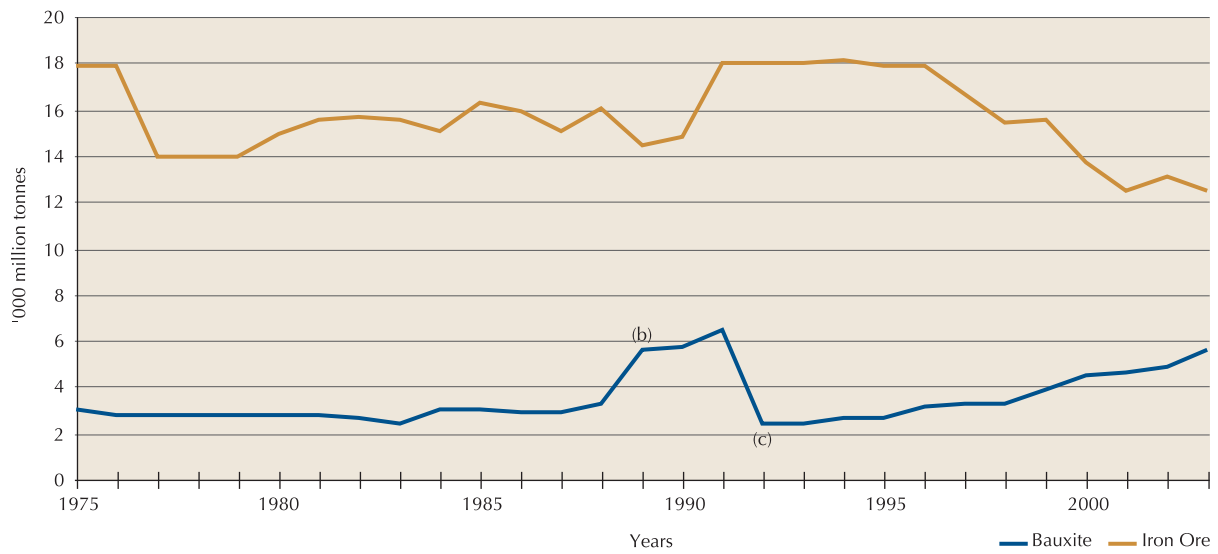
EDR for iron ore has declined since 1996 due to the combined impacts of mining companies re-estimating ore reserves and mineral resources more conservatively so as to comply with requirements of the JORC Code, and increased rates of mine production.

FIGURE 1. Trends in Economic Demonstrated Resources (EDR) for major commodities since 1975 (For explanations relating to (a), (b), (c)... refer to 'Trends in Australia's Economic Demonstrated Resources of major mineral commodities').

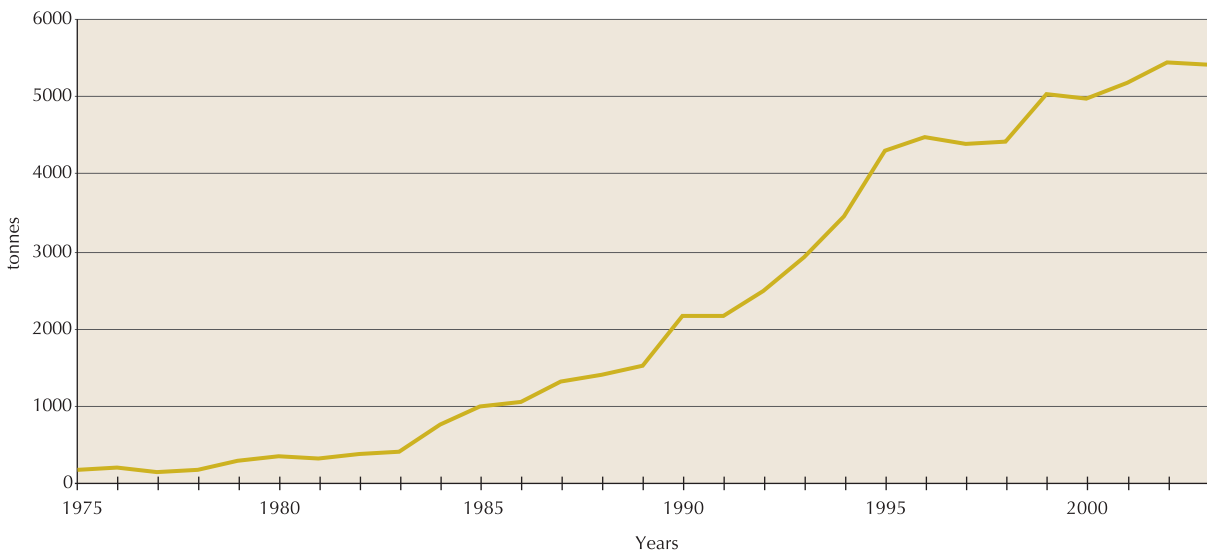
Black Coal (recoverable)



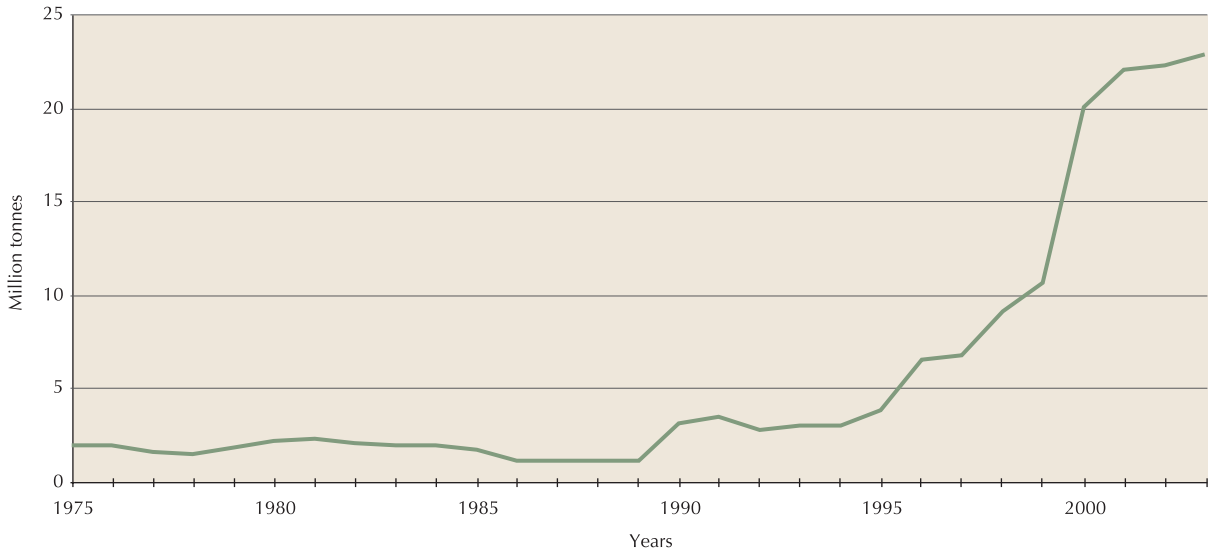
Bauxite, Iron Ore



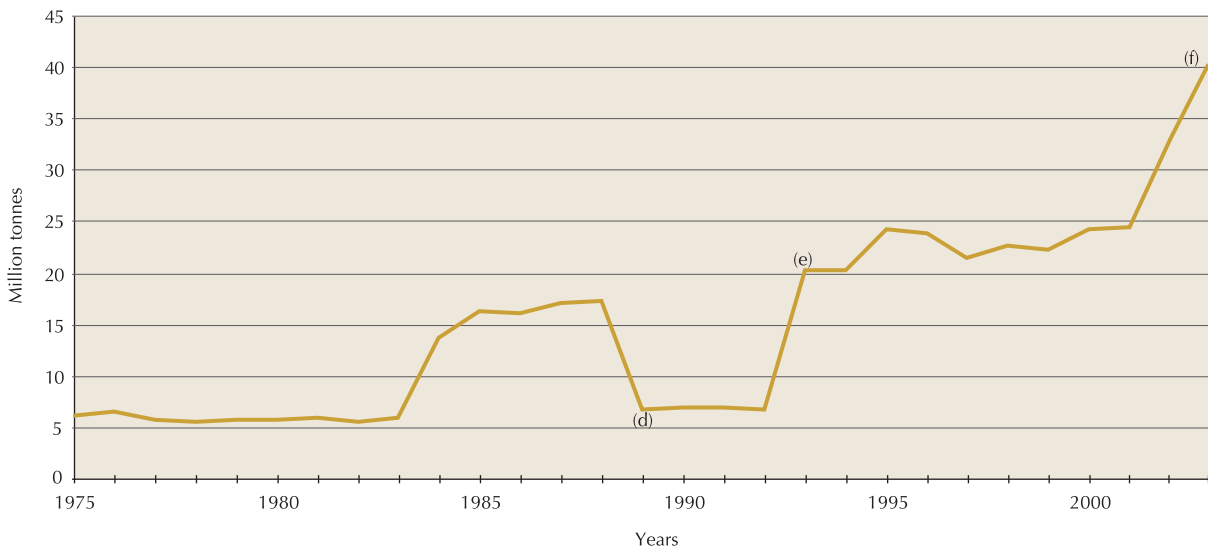
Gold



Nickel



Copper



Lead, Zinc

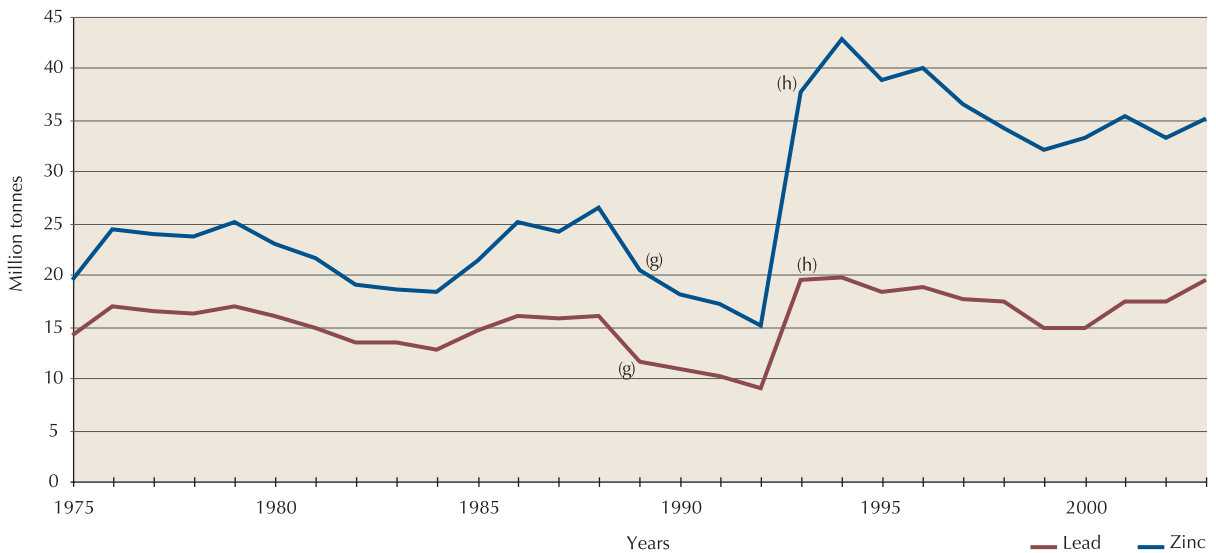
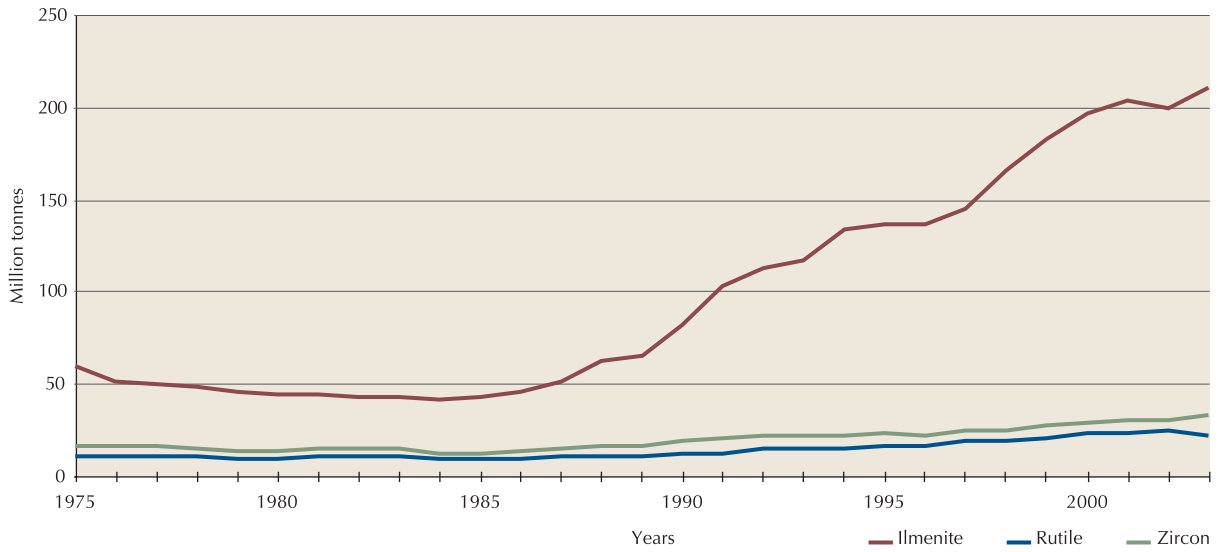
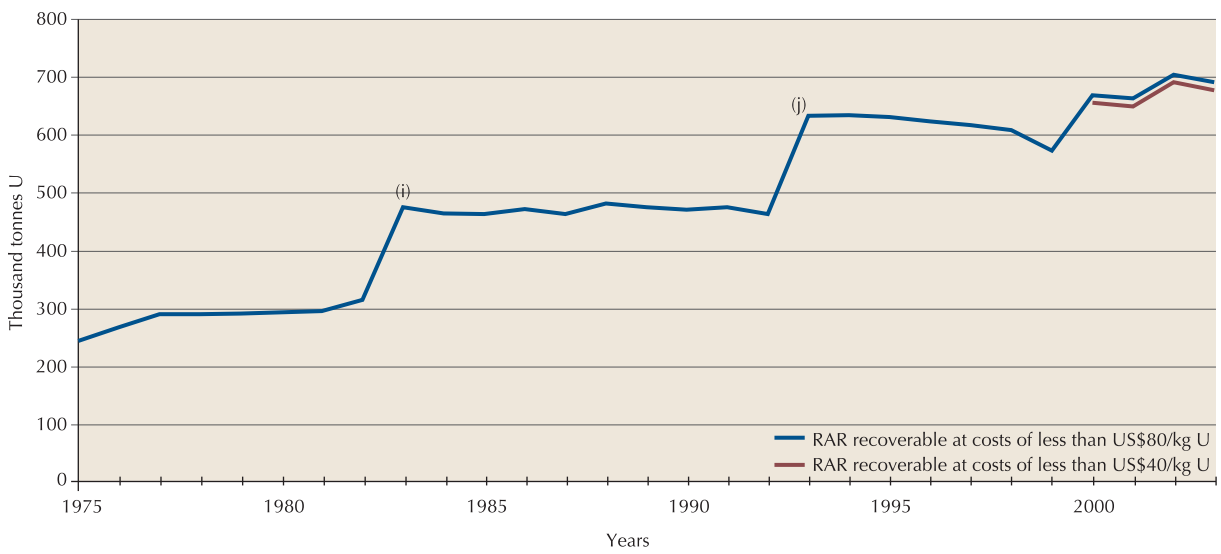


FIGURE 1: Trends in Economic Demonstrated Resources (EDR) for major commodities since 1975 (continued).

Mineral Sands



Uranium (recoverable)



GOLD

Gold EDR has increased steadily since 1975 with a clear increase in the rate of growth in the early 1980s. Much of the increase can be attributed to the successful introduction of the carbon-based processing technology which allowed the profitable processing of relatively low grade ore deposits. In addition, the higher than previous prevailing gold prices (denominated in US\$) supported high levels of exploration for gold to the extent where gold accounted for over half of the total mineral exploration expenditure in Australia. Increased exploration contributed to the increases in EDR.

NICKEL

The EDR for nickel increased during the period 1995 to 2001 by 18.2 Mt. This was mainly due to progressive increases in resources of **lateritic deposits** at Bulong, Cawse, Murrin Murrin, Mt Margaret, Ravensthorpe (all in WA), Marlborough (Qld), Syerston and Young (NSW). Australia's EDR of nickel doubled in 2000 (compared to the level at the end of 1999) – this dramatic increase was due to further large increases in resources at the Mt Margaret and Ravensthorpe deposits, and deposits in the Cawse Southern Province (WA). In addition, during the period 1995 to 2001 there were increases in resources of **sulphide deposits** at Yakabindie, and discoveries of the Silver Swan and Cosmos high-grade sulphide deposits (all in WA).

From 2001 onwards, the sharp rises in market prices for nickel led to increased expenditures on exploration and on evaluation drilling at many known deposits. This contributed to a further increase in total EDR of 0.9 Mt for **sulphide deposits** at Perseverance, Sally Malay, Maggie Hays, Emily Ann, Honeymoon Well and deposits in the Forrestania area (all in WA), Avebury (Tas.), and remnant resources at several sulphide deposits in the Kambalda region including Miitel and Wannaway deposits. During this period, WMC Resources sold several of its mines in the Kambalda region to various junior mining companies. These companies increased the resources at these mines and deposits by further drilling and re-assessments.

COPPER

Following the adoption of the JORC Code by the Australian mineral industry, many companies first used this code for reporting their copper resources in 1989. These companies re-estimated mineral resources in order to comply with the Code. This resulted in a sharp fall in Australia's copper EDR in 1989 ('d').

The sharp increase in copper EDR in 1993 was due mainly to an increase in company announced resources for Olympic Dam deposit (SA). Additional resources were also reported for Ernest Henry (Qld), North Parkes (NSW) and other smaller deposits ('e').

Re-assessments of copper resources by Geoscience Australia in 2002 and 2003 resulted in further transfers (reclassification) of Olympic Dam resources into EDR ('f').

LEAD, ZINC

The adoption of the JORC Code in 1988 by the Australian mineral industry led to a re-estimation of mineral resources by many companies to align with the Code, and some re-assessments of resource data for other deposits by the former Bureau of Mineral Resources. This resulted in a sharp fall in Australia's lead and zinc EDR in 1989 ('g').

Increases in EDR for lead and zinc in 1993 were due to re-classification of Paramarginal Resources into EDR for McArthur River (NT) and Hilton deposits (Qld). Additional resources were also reported for Century and Cannington deposits (Qld) ('h').

MINERAL SANDS

Increases in EDR of **ilmenite** from 1996 to 2003 resulted from discovery and subsequent evaluation drilling of heavy mineral sands deposits in the Murray Basin – these deposits are in Victoria (Wemen and Woornack), NSW (Gingko and Snapper) and SA (Mindarie project). In addition, from 1998 onwards there were progressive increases in resources at mineral sands deposits in the North Swan Coastal Plain area north of Perth, and the Blackwood Plateau region (includes the Beenup deposit) in WA.

URANIUM

The majority of Australia's uranium deposits were discovered between 1969 and 1975 – approximately 50 deposits (15 with significant resource estimates) were discovered during this short period. Since 1975, only another four deposits have been discovered – of these four, only one deposit (Kintyre in the Paterson Province of WA) has Reasonably Assured Resources recoverable at less than US\$40/kg U (equates with EDR). Hence, the progressive increases in Australia's EDR for uranium from 1975 to the present (as shown on Fig. 1) were due to on-going delineation of resources at known deposits.

From 1983 onwards, the Olympic Dam deposit has been the major contributor to increases in Australia's EDR. The large increases shown on Fig. 1 were due to the following:

- in 1983, initial resource estimates for Olympic Dam and Ranger No. 3 Orebody (NT) made by the former Australian Atomic Energy Commission ('i').
- in 1993, further increases in EDR for Olympic Dam (based on estimates reported by WMC Resources Ltd), and first assessment of resources for the Kintyre deposit by the former Bureau of Mineral Resources ('j').
- in 2000 and 2002, increases were due to continuing additions to the Olympic Dam resources.

COMMODITY REVIEWS



Construction of the Broadmeadow punch longwall coal mine, BHP Billiton Mitsubishi Alliance Bowen Basin, Queensland.
Inset: Broadmeadow punch longwall mine entrance (main gate).
(Geoscience Australia, Bill McKay)

Bauxite

Bauxite is a heterogeneous naturally occurring material from which alumina (Al_2O_3) and aluminium are produced. The principal minerals in bauxite are gibbsite ($\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$), boehmite ($\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$) and diaspore, which has the same composition as boehmite but is denser and harder.

Over 85% of the bauxite mined globally is converted to alumina for the production of aluminium metal, an additional 10% goes to non-metal uses in various forms of specialty alumina, and the remainder is for non-metallurgical bauxite applications. In nearly all commercial operations, alumina (Al_2O_3) is extracted (refined) from bauxite by a wet chemical caustic leach process known as the Bayer process. Alumina is smelted using the Hall-Heroult process to produce aluminium metal by electrolytic reduction in a molten bath of natural or synthetic cryolite (NaAlF_6).

Australia's aluminium industry is a large integrated sector of mining, refining, smelting, semi-fabrication and recycling, which is of major economic importance nationally and globally. The total value of all sector exports was over \$7.8 billion in 2003. The industry consists of five bauxite mines, seven alumina refineries, six primary aluminium smelters, twelve extrusion mills and two rolled product (sheet, plate and foil) mills. It directly employs over 16 000 people (indirectly many more) and is particularly important in regions such as North Queensland, Hunter Valley (NSW), 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 the industry. Deposits in these regions 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 uneconomic to develop but are a significant potentially viable future resource.

EDR of 5.5 Gt in 2003 represented an increase of over 14% compared to the previous year. This was the net effect of new drilling, changes in cut-off grades, mining depletion and reclassification of resources. The most significant impact resulted from the application of revised economic parameters by Rio Tinto, which permitted development of a new resource model for the Weipa mine and the subsequent transfer of mineral resources to ore reserves. Subeconomic demonstrated resources decreased by slightly less than 1.9 Gt following upgrading of resources to EDR for Weipa. Expansion of the Weipa bauxite mine includes a significant increase in production from the mining and processing of lower grade ores. Inferred resources fell by over 50% to 0.6 Mt, which reflects an adjustment by industry to align with JORC standards, particularly companies in Western Australia.

Accessible EDR

Less than 6% of bauxite EDR is inaccessible for mining. This involves small areas of the Darling Range (WA), within mining leases, where for environmental reasons bauxite is not available for extraction. The ratio of AEDR to current mine production indicates a resource life of around 90 years. The potential for delineating additional economic resources is considerable.

JORC Reserves

Approximately 40% of AEDR comprises JORC Code reserves. The remaining represents resources assessed by Geoscience Australia as being economically recoverable from industry's *measured* and *indicated* categories of *mineral resources*, as defined under the JORC Code.

Exploration

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

Production

In 2003, production totalled 55.6 Mt of bauxite, 16.5 Mt of alumina and 1.9 Mt of aluminium (ingot metal). In comparison to 2002 these represented increases of 2.7%, 0.9% and 1.1% respectively. Very little Australian bauxite is exported and although ABARE does not report tonnage exported they do detail exports valued at \$180 million, which was 5% higher than in 2002. Alumina exports rose by 0.7 Mt (5.2%) in 2003 but aluminium exports fell slightly.

World Resources

Based on USGS data for other countries, Australia's demonstrated bauxite resources of 7.6 Gt rank second in the world after Guinea and ahead of Brazil, Jamaica and China.

Industry Developments

Production and expansion of capacity in the aluminium industry continued strongly in 2003. Expansion of the Weipa bauxite mine in Queensland is underway to increase production capacity to 16.5 Mtpa, mostly to supply the new Comalco Alumina Refinery at Gladstone. Construction of the US\$750 million refinery is on schedule and initial shipments from the 1.4 Mtpa plant are expected in 2005. In June 2003, Comalco signed a long-term supply agreement with Norsk Hydro, under which the Norwegian industrial group will buy 500 kt of alumina per year for more than 20 years to feed its aluminium smelters in Australia and elsewhere.

In late 2003, Alcan Gove Pty Ltd completed an Environmental Impact Statement (EIS) for its proposed \$1.5 billion expansion of the Gove alumina refinery in the Northern Territory. The expansion would increase alumina production capacity of the refinery from 2 Mtpa to around 3.5 Mtpa and convert all of Alcan Gove's bauxite output into alumina. Submission of the EIS to the Northern Territory Government in early 2004 is to be followed by further community consultation during the public comment period.

Alcoa Worldwide Alumina and Chemicals (AWAC) is owned by Alcoa Inc. 60% and Alumina Ltd 40% (created in late 2002 when WMC Ltd's alumina assets were demerged from its other businesses). AWAC has integrated mining and refining operations in Western Australia and aluminium smelting interests in Victoria (Point Henry smelter 100% ownership and Portland smelter 55% controlling interest). In 2003, the refineries produced approximately 7.9 Mt of alumina and the smelters a record 545 000 t of aluminium. During the year, the company received the Society of Ecological Restoration International Model Project Award (SERI Award) for Outstanding Contribution to the Field of Ecological Restoration. The award recognised effort in returning the plant species richness of jarrah forest in rehabilitated bauxite mines in Western Australia to a level equal to that of the surrounding native forest.

Black Coal

The main use for coal is in the generation of electricity. Other uses are in the production of coke for the iron and steel industry and as a source of heat in cement and food manufacturing. Australia has substantial resources of high quality black coal. New South Wales and Queensland account for the majority of these resources. Locally important coal resources occur in Western Australia, South Australia and Tasmania. The high quality black coal resources in New South Wales and Queensland are the basis for a major export industry.

Resources

In situ EDR for 2003 decreased 5.0% to 54.6 Gt and recoverable EDR decreased 3.5% to 38.3 Gt. These decreases were due to production, the reassessment and reclassification of some resources and a number of deposits being significantly downgraded. Queensland (56%) and New South Wales (40%) have the largest proportions of recoverable EDR in Australia.

Significant decreases in recoverable EDR were reported at Wandoan, Pentland, Theodore, Grosvenor, Moranbah North, Wambo and Bargo. In 2003, mine closures occurred at Swanbank, Southland, Stratford and South Bulga. Recoverable EDR increased at New Acland, Moranbah South and Felton and the newly reported deposits of Wilpinjong, Wonbindi, Mt Fort Cooper, Millenium, Foxleigh South and Codrilla.

In situ paramarginal demonstrated resources (PDR) increased by 108% to 8.1 Gt and recoverable PDR increased by 44% to 4.6 Gt due largely to the reclassification of resources in a number of deposits including Togara North and Togara South. In situ subeconomic demonstrated resources (SDR) decreased 46% to 12.7 Gt and recoverable SDR decreased 13% to 9.3 Gt mainly as a result of reassessment of many of Rio Tinto's coal deposits. In situ inferred resources remained almost unchanged at 84.7 Gt and recoverable inferred resources decreased about 1% to 52.3 Gt. The large inferred resource differences reported at Callide, Moura, South Walker, Saddlers Creek and Wambo resulted in only a minor net loss to Australia's total inferred resources.

Accessible EDR

Nearly all black coal EDR is accessible with only a relatively small tonnage at Hill River (WA) being inaccessible within State Reserves. The resource life of the Accessible EDR of 38.2 Gt is over 100 years at current rates of production.

JORC Reserves

JORC reserves are 14.2 Gt or 37% of Accessible EDR. Included in the 14.2 Gt are Geoscience Australia estimates of reserves at 19 operating mines that have no reported JORC reserves. This constituted 2.5 Gt or about 6% of Accessible EDR. BHP Billiton, Rio Tinto, Xstrata Coal and Anglo Coal manage about 69% of JORC reserves in Australia. The resource life of the JORC reserves of 14.2 Gt is close to 40 years.

Exploration

Data published by ABS show that exploration expenditure for coal in 2003 totalled \$84.7 million, which is an increase from \$61.2 million in 2002. Expenditure in Queensland was \$59.9 million or 71% of the total. Exploration also occurred in New South Wales, South Australia, Western Australia and Victoria.

Production

In 2003 Australia produced 358.4 Mt of raw coal (348.0 Mt in 2002), which yielded 280.7 Mt of saleable coal (273.4 Mt in 2002). Exports of black coal during 2003 were 111.4 Mt of coking coal valued at \$6.8 billion and 103.2 Mt of steaming coal valued at \$4.0 billion. ABARE forecasts Australia's saleable production will grow to 343.5 Mt by 2008–09 of which 267.7 Mt will be exported.

In 2003 Queensland (56%) and NSW (41%) produced over 97% of the raw coal tonnage. Open-cut mining accounted for 77% of the raw coal production and at the end of 2003 there were 101 operating black coal mines in Australia (63 open cut and 38 underground). Employment reached 21 700 by the end of 2003 and annual raw coal production per employee for 2003 was 16 200 t. Domestic consumption of black coal totalled 67.8 Mt with power stations using 57.1 Mt (or 84%).

World Ranking

Australia has 5% of the world's recoverable black coal EDR and ranks sixth behind USA (27%), Russia (19%), China (12%), India (10%) and South Africa (6%).

Australia produced about 7% of the world's black coal in 2003 and ranked fourth after China (35%), USA (24%) and India (9%).



Goonyella coal mine owned by BHP Billiton Mitsubishi Alliance (BMA), Bowen Basin, Queensland.
(Geoscience Australia, Bill McKay)

INDUSTRY DEVELOPMENTS – QUEENSLAND

Pacific Coal: The \$460 million **Hail Creek** open-cut mine was opened in late 2003. When fully operational the mine is planned to produce 5.5 Mtpa of hard coking coal for export. Pacific Coal is scheduled to commence longwall mining in the Ti Tree area at the **Kestrel** mine in January 2004. At the **Meandu** open-cut mine production capacity has been increased from 5 to 7 Mtpa to supply coal to the Tarong and the newly commissioned Tarong North power stations.

BHPBilliton Mitsubishi Alliance (BMA): In late 2003 construction commenced on a new punch longwall underground mine at **Goonyella**. The US\$67 million **Broadmeadow** mine (refer Commodity Review cover page) will produce up to 3.6 Mtpa of coking coal commencing in late 2005. BMA is proposing to develop another punch longwall mine at the **Saraji** open-cut coking coal mine. At the **Blackwater** mine BMA is planning to build a new 14 Mtpa coal handling and processing facility.

Xstrata Coal: At **Newlands**, construction commenced on the Northern underground punch longwall mine as a replacement for the Southern underground mine. Production is scheduled to commence in late 2005 and is expected to produce up to 8 Mtpa. The Southern open-cut was completed in early 2003 and was replaced by the recommencement of the Eastern Creek open-cut later in the year. Development of the Rolleston open-cut thermal coal mine is planned for 2004 and a production of 6 Mtpa is expected by 2007. Xstrata is proposing to develop the Suttor Creek deposit at Newlands to replace the Main deposit which will cease in mid-2004.

Anglo Coal: During 2003, construction continued at the **Grasstree Colliery**. The new underground longwall coking coal mine is scheduled to commence in 2005 to replace the depleted resources at the **Southern Colliery**. The **Oak Park** open-cut mine being developed by Anglo will replace production from the **German Creek East** mine. At **Moura** the operations are being extended southward into the northern part of the **Theodore** deposit. Anglo plan to produce 6.2 Mtpa of open-cut thermal coal over a seven year mine life at Theodore.



Loading a coal haul truck at the Moura mine, Bowen Basin, Queensland.
(Anglo Coal Australia)

Macarthur Coal: In August 2003 the \$66 million **Moorvale** open-cut mine commenced with a capacity of 1.6 Mtpa. At **Coppabella**, the Transport Infrastructure Corridor (TIC) project was completed in December 2003. A feasibility study on the expansion of Coppabella by up to 1.0 Mtpa commenced in the third quarter.

Peabody Energy: Construction started on the \$195 million **Eaglefield** open-cut coal project in late 2003. Production will supplement coal from the nearby **North Goonyella** underground mine.

Wesfarmers: Wesfarmers plans to spend \$160 million to develop the **Curragh North** open-cut thermal coal mine. Production is scheduled to commence in late 2005 and will use the existing Curragh mine infrastructure and equipment.

INDUSTRY DEVELOPMENTS – NEW SOUTH WALES

BHP Billiton: The US\$410 million **Mount Arthur** open-cut mine commenced coal deliveries to Macquarie Generation in January 2003. The mine will be capable of producing up to 15 Mtpa of raw thermal coal when full production is achieved in 2006. Construction continued at the US\$170 million **Dendrobium** mine during 2003. The underground longwall mine will produce 5.2 Mtpa of coking coal when operations start in mid-2005. The Dendrobium commencement is planned to coincide with closure of the **Elouera Colliery**.

Coal and Allied: The **Warkworth Extension** received development approval in August 2003. This approval extends the life of the mine to 2020 and integrates the Warkworth and **Mount Thorley** operations with a new bridge over the Putty Road that is scheduled to be completed in early 2004. In October 2003, Coal and Allied submitted an Environmental Impact Statement for the integration of the **West Pit (Howick)** into the existing operations to maximise the resource recovery of the Hunter Valley Operations.

Xstrata Coal: The **Beltana** punch longwall underground mine commenced production in August 2003 at a rate of 5 Mtpa. Beltana replaces the **South Bulga** underground mine which closed earlier in 2003. At **Cumnock** the underground mine closed in September 2003 and lower cost open-cut operations continued. The integration of Xstrata's **Ravensworth East** and **Mount Owen** mines commenced in the latter half of 2003 and the conversion of the United mine from bord-and-pillar to longwall was completed.

Anglo Coal: The new **Kayuga** underground longwall operation at the **Dartbrook** mine is scheduled to commence full production in mid-2004. The **Saddlers Creek** deposit is being proposed by Anglo to replace the West Pit at the **Drayton** open-cut mine.

Centennial Coal: Construction of the \$185 million **Mandalong** project continued during 2003. Longwall mining is scheduled to commence in 2005 at a rate of 4.5 Mtpa. At the Springvale mine Centennial plans to incrementally expand production from 2.2 to 3.3 Mtpa over the next four years. During 2003, Centennial successfully introduced a new 'super place change' mining unit at the Clarence mine. Centennial is undertaking a feasibility study into the development of the Anvil Hill open-cut thermal coal mine.

Excel Coal: Studies are being undertaken to expand open-cut operations at **Wambo** from 4.2 Mtpa to 7.5 Mtpa and to recommence longwall operations. Excel won the contract to supply coal to Macquarie Generation from the **Wilpinjong** thermal coal deposit near Mudgee. An open-cut mine is planned to produce between 5 and 7 Mtpa by 2007.

Gloucester Coal: The **Bowens Road North** mine replaced the depleted **Stratford** mine during 2003 and operations also commenced at the nearby Duralie mine. These new mines allow Gloucester's total production to be maintained at 2 Mtpa until 2011.

White Mining: Construction of the \$110 million **Ashton** open-cut mine started in September 2003. The project is expected to commence in early 2004 at a rate of 2 Mtpa.

Austral Coal: The \$135 million **Tahmoor North** capital works program continued during 2003. Austral Coal expected longwall mining to commence in mid-2004 at a rate of up to 3.6 Mtpa.

Newpac Pty Ltd: The **Newpac No. 1** mine opened in February 2001 as the **Nardell Colliery** but production was suspended in October 2003. The mine reopened under new ownership and name in December 2003.

OTHER PROPOSED DEVELOPMENTS

Some proposed developments in NSW and Qld include:

- **Tasman** underground thermal coal mine at a rate of 1.0 Mtpa using bord-and-pillar methods (Newcastle Coal Company),
- **Belmont** open-cut thermal coal mine with a capacity of 1.5 Mtpa (Whitehaven Coal Mining),
- **Bickham** open-cut thermal coal mine with a production of up to 2.5 Mtpa (Bloomfield Collieries),
- **Sandy Creek** underground thermal coal mine (Muswellbrook Coal Company),
- **Vermont** open-cut mine with a production of 2.5 Mtpa located about 15 km NE of Dysart (Bowen Basin Coal Pty Ltd),
- **Glen Wilga** \$60 million 0.5 Mtpa open-cut thermal coal mine near Chinchilla (Qld) (Tarong Energy),
- **Minerva** thermal coal mine (Qld) costing \$60 million for a capacity of 0.8 Mtpa (Felix Resources).

At **Collie** in Western Australia, thermal coal producers Griffin Coal and Wesfarmers are proposing to construct power stations adjacent to their mines. In South Australia NRG Flinders is planning an expansion of thermal coal production from 3 to 3.8 Mtpa using existing equipment. During 2003 a new open-cut thermal coal mine opened at Cullenswood near St Marys in Tasmania.

The Stage 6 expansion of the **Dalrymple Bay Coal Terminal** (Qld) was completed in June 2003. The expansion included a new berth (Berth 3) and a new shiploader. These facilities have increased the terminals capacity from 45.5 to 56 Mtpa at a cost of \$115 million. Prime Infrastructure has

developed plans that could raise capacity to 74 Mtpa. In June 2003 the RG Tanna Coal Terminal's (Qld) \$80 million expansion project was officially opened. The project has boosted the terminal's capacity from 30 to 40 Mtpa. The expansion included a new wharf extension, a berth pocket and departure channel and the construction of stockpile No. 15. There are plans in place for the staged expansion of the ports capacity to 60 Mtpa.

In early 2003, CSIRO released research into the structure of the Bowen Basin. The Supermodel 2000 project covered 2500 km² along the basins western limb covering the Moranbah and German Creek seams. Research is now being done on the eastern extent of the basin. The Cooperative Research Centre (CRC) for Coal in Sustainable Development undertakes collaborative research to find cleaner and more efficient ways of extracting energy from coal. In 2003 the CRC had six research programs including Current and Transitional Power Generation and Ironmaking. The COAL21 participants had the inaugural meeting in March 2003. COAL21 is a national initiative aimed at significantly reducing and eliminating emissions of greenhouse gases from coal based electricity generation.

Brown Coal

Deposits of brown coal occur in Tertiary (age 15 to 50 million years) sedimentary basins in all States of Australia. The largest deposits are in the Gippsland Basin, where the La Trobe Valley Coalfield contains some of the thickest brown coal seams in the world. The coal is up to 330 m thick and is made up of four main seams, separated by thin sand and clay beds.

Brown coal is mined only in Victoria where it is mainly used as a fuel for electricity generation. At Morwell, brown coal is also used to make briquettes for industrial and domestic heating. Brown coal can also be used to produce water gas, industrial carbon and it is used to decolourise and purify solutions.

Resources

Recoverable EDR for 2003 was 37.5 Gt a slight decrease on 2002 EDR due to production. Recoverable PDR and SDR remained unchanged at 39.0 Gt and 16.3 Gt respectively. Recoverable inferred resources decreased 2.0% to 100.8 Gt due to new data becoming available for the O'Sullivan's deposit, WA. All of Australia's EDR of brown coal is in Victoria and about 89% of the total EDR is located in the La Trobe Valley.

Accessible EDR

Approximately 80% of brown coal EDR is accessible for mining. Inaccessible resources include the APM Mill site which has a 50 year mining ban that commenced in 1980, the Holey Plains State Park and the Morwell township area. The resource life of the accessible EDR of 30.0 Gt is approximately 450 years.

JORC Reserves

No brown coal resource figures are JORC Code compliant. However, Geoscience Australia has estimated reserves at the operating mines from published information. Reserves are about 2.1 Gt with 70% being at Loy Yang. The resource life of published reserves is over 30 years.

Exploration

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

Production

Australian brown coal production for 2003 was 68 Mt all from Victoria. The La Trobe Valley mines of Yallourn, Hazelwood and Loy Yang produce about 98.5% of Australia's brown coal. Locally significant brown coal operations occur at Anglesea and Maddingley.



Satellite guided D11R dozers using the radial sector method to push coal to a feeder-breaker at the Yallourn brown coal mine, Victoria. (Yallourn Mine Alliance, Roche Thiess Linfox Joint Venture)

World Ranking

Australia has about 20% of world recoverable brown coal EDR, and is ranked second behind Germany (23%). Australia produces about 8% of the world's brown coal and is ranked third largest producer after Germany (20%) and USA (10%).

Industry Developments

About 18 Mt of brown coal is extracted annually at the **Yallourn** mine by the Roche Thiess Linfox (RTL) Joint Venture. The diversion of the Morwell River through the centre of the open-cut along an elevated channel will enable access to new coal reserves in the East Field Mine Extension and the Maryvale Field. Two satellite-guided D11R bulldozers have replaced 1950's era bucketwheel coal dredgers. The 10-year \$500 million mine expansion and power station upgrade will increase the projects life to about 2025.

At the **Loy Yang** mine, a 4.5 km deviation of the Hyland Highway east of the Loy Yang Power Station was opened in November 2003. The highway deviation clears the way for the continued expansion of the mine during the next 40 years. The Loy Yang mine will cut the existing Hyland Highway in mid to late 2004. Loy Yang Power plan to progressively upgrade the Loy Yang A power station by up to 235 MW's by 2008.

The South East Field at the **Hazelwood** mine will be exhausted by 2005. About \$100 million is being spent on development at West Field with the first coal cut in late 2003 and continuing until 2010. Development of West Field beyond 2010 requires the Strezlecki Highway and the existing Morwell River Diversion to be relocated. Work on the river and road diversions must begin in early 2005 to enable completion by 2010 and the continued supply of coal to the Hazelwood Power Station until at least 2030. Another \$240 million is being spent on such items as the power station and the environment. In April 2003 the Commonwealth Government granted the \$100 million development Major Project Facilitation status.

Feasibility studies are being undertaken by GTL Energy and International Power plc into the establishment of a high capacity gasification and gas-to-liquids plant adjacent to the Hazelwood Power Station. GTL Energy has also signed an agreement with US based Rentech to use its patented gas-to-liquids technology in Australia. A preliminary assessment showed that for a 4 500 tonne per day project, two million barrels of diesel and 1 million barrels of naphtha could be produced annually.

Australian Power and Energy Ltd (APEL) has access to the 3 Gt **Flynn** Coal Deposit (or over two billion barrels of sulphur free fuels). APEL plan to utilise the Shell coal gasification system and the Syntroleum gas to liquids system. Stage 1 of the Victorian Power and Liquids Project proposes the production of 52 000 barrels per day of fuel and 1000 MW's of electricity.

HRL Ltd has been granted an exploration licence over sufficient coal for the operation of a proposed 800 MW **Integrated Drying Gasification Combined Cycle** (IDGCC) power station. The IDGCC process has been demonstrated at the 10 MW scale and HRL are now planning to build a 100 MW intermediate scale plant in the next four years before constructing the 800 MW power station towards the end of the decade.

During 2003 the Victorian Government commenced the **Centre for Energy and Greenhouse Technologies** (CEGT) in the La Trobe Valley. The Centre is aimed at assisting the commercialisation of new energy technologies for mitigating greenhouse gas emissions. The Victorian Government is providing funding of up to \$14.25 million over three years, under its science, technology and innovations, and greenhouse strategies.

The **Cooperative Research Centre (CRC) for Clean Power from Lignite** has now been established 10 years. Currently the CRC has a total funding of \$50 million over seven years from July 1999. The CRC is developing technology to improve the operation of existing power stations and for future advanced technology power stations.

In 2003 the Victorian Department of Primary Industries released a new 3D picture of the coal resources in the La Trobe Valley. It is also available as a digital 3D model showing the distribution and quality of the thickest brown coal seams from Moe to Rosedale. The model will provide information on coal geology and resources and will assist with coal utilisation and land-use planning.

The **Eastern Star Gas Ltd Oak Park** brown coalbed methane pilot production project is 35 km west of the Melbourne CBD. The pilot project comprises five wells in the 17 m thick Maddingley seam, with four wells 300 m apart surrounding a central well. The wells have all been cased down to the top of the Maddingley seam and trial dewatering of the wells is continuing.

Copper

Australia is a major copper producer with mining and smelting operations at Olympic Dam (SA) and Mt Isa (Qld). Other significant copper producing operations are at Northparkes and Cadia-Ridgeway (NSW), Golden Grove and Nifty (WA), Ernest Henry, Osborne and Mt Gordon (Qld) and Mt Lyell (Tas). Copper and copper alloys are used in building construction, electrical equipment such as electrical cables, and industrial machinery and equipment.

Resources

Australia's EDR rose by 7.3 Mt to slightly more than 40 Mt, an increase of 22%. South Australia has the largest holdings of EDR with around 61% of the national total and its overall share increased by 7% in 2003. The majority of these resources are associated with the Olympic Dam deposit where EDR increased significantly through the reclassification of those demonstrated resources previously considered to be subeconomic, into EDR. This follows from due consideration of the rigorous resource estimation methodology applied by the company. Queensland has the second largest EDR with 19% of the national total, followed by Western Australia (10%) and New South Wales (6%). An increase in EDR for Queensland of 8% relates to increased resources predominantly at Mt Isa and to a lesser extent at Ernest Henry.

Subeconomic demonstrated resources decreased by 60% to 4.3 Mt largely reflecting the change at Olympic Dam. Western Australia has the most paramarginal resources with a 40% share, followed by Queensland (25%) and New South Wales (16%).

Inferred resources rose by less than 1 Mt (2%) to 22.1 Mt in 2003. This increase was mostly in Queensland where inferred resources rose by 8% or 0.4 Mt, primarily due to resource growth at Mt Isa. South Australia holds 51% of Australia's inferred resources followed by Queensland with over 20%.

Accessible EDR

All copper EDR is accessible.

JORC Reserves

JORC Code reserves account for approximately 50% of AEDR. The remaining AEDR comprise those measured and indicated resources (reported by mining companies) which Geoscience Australia considers will be economic over the long term.

Exploration

Spending on exploration for copper fell by 18.6% in 2003 to \$34.5 million. Exploration for copper was undertaken in all States and the Northern Territory. ABS data shows that spending in South Australia was \$11.7 million which represents 33.9% of total copper exploration in Australia. Exploration expenditures for copper in other states and the Northern Territory were not reported separately by ABS. The South Australian exploration was directed mainly at the search for Olympic Dam style mineralisation in the Gawler Craton and includes the resource definition drilling at Prominent Hill, where intersections including 41 m grading 6.06% Cu have been located structurally above a previous gold intersection of 57 m at 7.7 g/t.

Some of the encouraging exploration results reported in 2003 include:

Mineral Hill (NSW): Triako Resources Ltd at its Iodide South prospect reported 8.2 m at 12.4% Cu and 1.2 g/t Au, 14.6 m at 1.5% Cu and 6.2 g/t Au and 5.6 m at 1.4% Cu and 3.2 g/t Au.

Cadia (NSW): Newcrest Mining Ltd identified a large porphyry-style system at its Gooleys North prospect, with an intersection of 743.4 m at 0.17 g/t Au and 0.10% Cu.

Cloncurry (Qld): Cloncurry Mining Company reported an inferred resource of 0.875 Mt at 1.65% Cu and 1.0 g/t Au at the Kangaroo Rat prospect. Drill results include 9 m at 4.6% Cu and 0.98 g/t Au, 6 m at 3.1% Cu and 2.1 g/t Au and 11.2 m at 2.14% Cu and 1.4 g/t Au.

Greenmount (Qld): Also near Cloncurry, Matrix Metals reported a high-grade zone at its Greenmount deposit with an intersection of 9.2 m at 5.67% Cu. Greenmount has a measured and indicated oxide resource of 7.4 Mt at a grade of 1% Cu.

Kundip (WA): Tectonic Resources commenced a resource definition drilling program and a scoping study on mining options. Previous drill intercepts included 15 m grading 13.4g/t Au, 3.6% Cu and 18g/t Ag, and 4.2 m at 3.8 g/t Au, 2.7% Cu, and 13g/t Ag over a 1 km strike length.

Balcooma (Qld): Kagara Zinc began evaluating a high-grade supergene copper resource with intersections of 8.1 m at 16.8% Cu and 8 m at 13.5% Cu and 7.3% Pb up-plunge from the primary zinc-lead mineralisation near its Mount Garnet operation.

Jaguar (WA): Jabiru Metals reported extensional drilling intersected 5.03 m at 4.36% Cu and 7.49% Zn in an area where prior conceptual models projected an ore thickness of 1 m. The company is currently working on a new resource for Jaguar, previously calculated as an inferred resource of 1.72 Mt grading 3.6% Cu, 11.9% Zn and 127g/t Ag.

Roseby (Qld): Universal Resources reported an inferred and indicated oxide resource of 60 Mt at 0.77% Cu. The Roseby project consists of several deposits including Blackard, Little Eva, Lady Clayre, Bedford, Longamundi and Great Southern. More recent drilling intersected 186 m at 2.4% Cu from near surface.

Production

In 2003, Australia's mine production was 829 kt of contained copper, 6% less than 2002 (883 kt). Queensland continued to dominate production with 436 kt, 8% less than in 2002, and accounting for 53% of Australian production, down from 54% in 2002. South Australia remained the second largest producer with 160 kt (down 10%), representing 19% of Australia's production. Other production was: NSW (154 kt, up 14%), WA (49 kt, down 14%), and Tas. (30 kt, down 19%).

The value of Australia's exports of copper concentrates and refined copper totalled \$2.02 billion, 1% more than in 2002 (\$2.00 billion). The increase reflects higher exports, which were up 3% from 684 kt in 2002 to 704 kt in 2003. Copper prices were 5% lower in 2003 at an average of \$2735/t, down from an average of \$2871/t in calendar 2002.

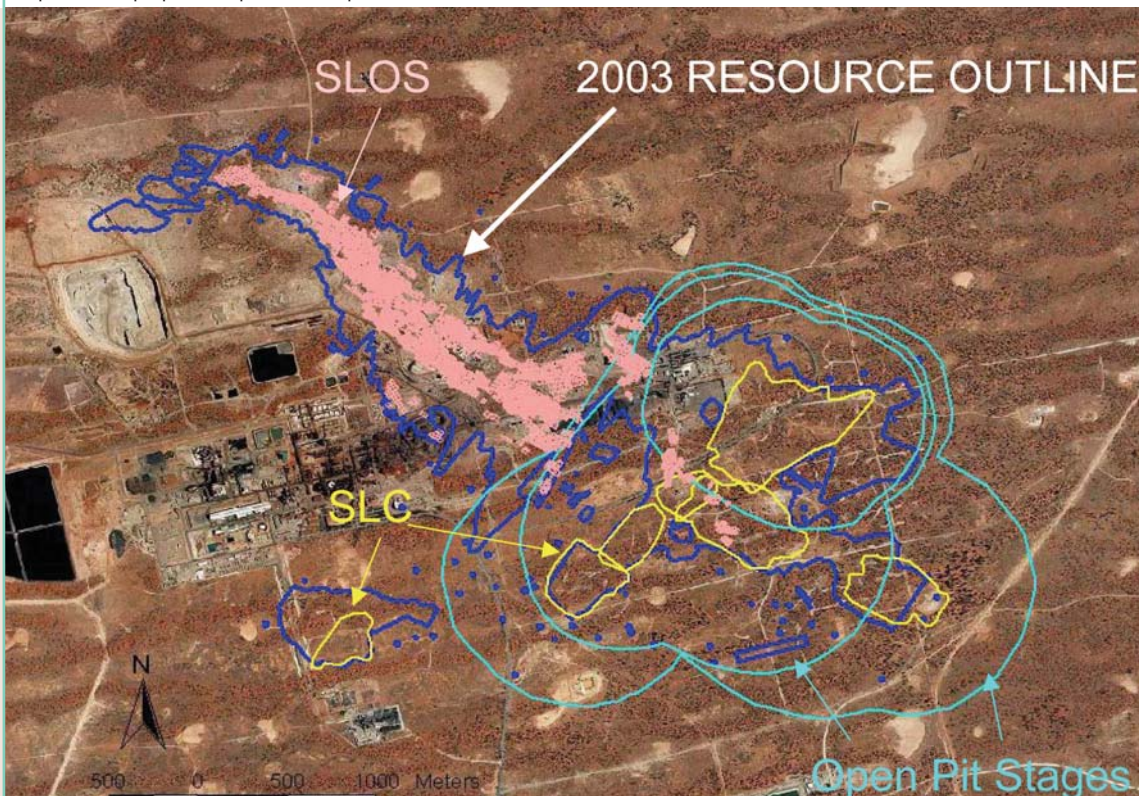
World Ranking

Based on USGS data for other countries, Australia has the second largest EDR of copper (8%) after Chile (31%) and ahead of USA and Indonesia (both 7%) and Peru, Poland and Mexico (all 6%). As a producer, Australia ranks fourth (6%) in the world after Chile (35%), USA and Indonesia (both at 8%).

Industry Developments

Olympic Dam (SA): Copper output in 2003 from WMC Resources' Olympic Dam mine, which has the world's eighth largest copper reserves, was down 10% on 2002 to 160 080 t refined copper as a result of planned major maintenance and subsequent problems at the smelter and in the sulphuric acid plant. Production for 2004 is anticipated to be 235 ktpa of copper when the newly commissioned copper solvent extraction plant is at full capacity. In May 2004, WMC Resources Ltd announced a \$50 million feasibility study into options to further expand production and to develop a preferred

Possible mining methods being studied for the proposed expansion of operations at Olympic Dam mine, South Australia. The current and proposed areas to be mined by sub-level open stoping (SLOS) methods are shown in the northern portion of the orebody. Sub-level caving (SLC) and open pit mining methods are being considered for the southern portion of the orebody as part of the proposed expansion of operations. (WMC Resources Ltd)



'life of mine' plan by 2006. Early studies have shown that Olympic Dam could produce up to 350 ktpa copper by extending underground mining and in excess of 500 ktpa copper by developing an open pit mine on the southern ore body additional to existing underground operations.

A major drilling campaign continued during 2003 to explore and delineate the southern orebody, the results of which will be used to evaluate the various mining options as part of the study.

Mt Isa (Qld): Xstrata Plc reported that 2003 production was impacted by difficult mining conditions during the first half of the year with annual mine production down by some 7% on 2002. A significant increase in underground development at both the X41 and Enterprise mines (at Mount Isa) is aimed at countering anticipated falling grades by increased production in 2004.

Whim Creek (WA): Straits Resources announced that it would develop the deposit near Port Hedland with first production from the open pit expected in late-2004. Straits will use the plant and equipment from its former Girilambone mine in New South Wales. It is expected that over 50 kt of copper will be produced over a four year operational life.

Tritton (NSW): Tritton Resources was floated by Straits Resources to develop the Tritton copper project, near Girilambone, based on a total resource of 14 Mt at 2.7% Cu. The operation will initially mine 660 ktpa of ore rising to 900 ktpa in the fifth and following years. Mining will be by underground methods with some ore supplied from a small open pit. Development costs for the project are expected to be about \$38.5 million.

Mt Gordon (Qld): Aditya Birla Group, one of India's largest business houses purchased Mt Gordon from the Western Metals receiver in a deal that avoided shut down and preserved the bulk of the workforce and supplier arrangements.

Nifty (WA): Aditya Birla Group is determining the viability of a 2.5 Mtpa underground development that will increase production from 27.5 ktpa to 100 ktpa. Previous owner, Straits Resources sold the project to Birla earlier in 2003 for \$148.2 million.

Lady Annie (Qld): Buka Minerals completed a pre-feasibility study for a 13 ktpa heap leach solvent extraction-electrowinning operation based on reserves of 4.4 million tonnes grading 1.8% Cu containing 79 kt of copper and costing \$30 million to develop.

Other developments included:

- **Ivanhoe Mines** acquired all the mining and exploration leases held by Selwyn Mines, and
- the copper smelter at **Port Kembla** (capacity of 120 ktpa copper) owned by a Japanese consortium, closed during the year because of lower copper prices.

Diamond

Diamond is composed of carbon and is the hardest known natural substance, but a sharp blow can shatter it. It also has the highest thermal conductivity of any known material at room temperature. Diamonds are thought to form 150–200 km below the Earth's surface at high temperatures (1050–1200°C) and pressures (45–55 kilobars). They are carried to the surface within kimberlite and lamproites that intrude through the crust. These intrusions form narrow cylindrical bodies, called 'pipes' and only a very small proportion have significant diamond content. When pipes are eroded, liberated diamonds may accumulate in alluvial deposits. Diamonds may be found far from their source as their hardness allows them to survive multiple episodes of erosion and deposition.

The quality of diamonds is subdivided into gem, near gem and industrial categories. In rare cases, up to 90% of diamonds in a deposit are of gem quality but most economic deposits contain 20 to 40% gem quality diamonds. Current uses for diamond include jewellery, stone cutting and polishing, computer chip manufacture, machinery manufacture, mining and exploration, construction and transportation services. A large proportion of industrial diamond is manufactured and it is also possible to produce synthetic diamonds of gem quality.

Resources

EDR for gem/near gem was 72.2 Mc and industrial 75.1 Mc, both up 7% compared with 2002 as a result of reassessment of resources at the Argyle mine.

Accessible EDR

All diamond EDR is accessible for mining.

JORC Reserves

JORC Code reserves account for almost all AEDR. The remaining AEDR comprise those measured and indicated resources (reported by mining companies), which Geoscience Australia has assessed as being economic in the long term.

Exploration

ABS data indicate that expenditure on exploration for diamond in Australia in 2003 was \$27.6 million, down 15% on 2002. Exploration was concentrated in Western Australia, notably the Kimberley region, Northern Territory and South Australia.

Airborne gravity surveys flown by Gravity Capital in the Kimberley region identified new targets at Ellendale (20 targets) for Kimberley Diamond Co, at North King George (9) for Striker Resources and AKD Limited, and Phillips Range (38) for Thunderella Exploration. Follow-up drilling at Ellendale in 2003 identified two new pipes and an alluvial palaeo-channel.

Seppelt (WA): Striker Resources NL reported bulk sampling of its Seppelt 2 pipe in the North Kimberley region had indicated a grade of about 2 cpt with gem quality diamonds up to 8.5 carats in size. Initial micro diamond results for the Seppelt 5 pipe are consistent with Seppelt 2. A zone of high-grade kimberlite at Seppelt now extends over 3 km in length, encompassing both the Seppelt 2 and Seppelt 5 kimberlite occurrences which are 2.5 km apart. A sample of 3566 carats from Seppelt 2 was valued at US\$48 per carat using a +1.5mm lower screen cut-off, and around US\$35 per carat using a 1 mm cut-off.

Timber Creek (NT): Tawana Resources has so far found 660 carats, however reliable values cannot be assigned to diamonds from valuation parcels of less than 2000 carats. A coating around the diamonds has delayed recovery and a 'diattech' detection method is being trialled. To date, this method has been more successful than x-ray methods for detecting diamonds, and in addition, has detected yellow diamonds not previously recovered by either grease tables or x-rays.

Other areas of diamond exploration in 2003 included: the Altjwarra Craton NT (Elkedra Diamonds); the Pilbara region WA; and Copeton NSW (Cluff Resources Pacific).

Production

Australia produced 31 Mc of diamond in 2003, making it the world's largest producer of diamond by weight. Australia is the largest producer of industrial grade diamond and the second largest producer of gem/near gem diamond. Botswana, a close second in terms of diamond production by weight, is the leading diamond producer by value with Australia ranked eighth.

Nearly all production was from the Argyle mine in the Kimberley region of Western Australia, which produced 30.9 Mc of mostly industrial and cheap gem quality diamonds. Argyle production was down nearly 8% on 2002 production and reflected the mining of lower grade material in the Northern Bowl and the cessation of mining of alluvial diamonds in late 2002. A total of 9787 t of ore was mined from the Argyle AK1 pipe with an average grade of 3.16 cpt, comparable with 2002 figures (3.19 cpt).

At Ellendale in the West Kimberley region, 57 000 carats were produced in 2003 with the top several metres of the Ellendale 9 pipe yielding high-value fancy yellow gem diamonds. Recent large diameter drilling and sampling has upgraded the resource at Ellendale 9, 4 and the satellite pipe to 90 Mt at 6.2 carats per hundred tonnes.

At Merlin in the Northern Territory, a total of 62 000 carats was mined in 2003.

World Ranking

Australia's EDR of industrial diamond ranks third (16% of current world total EDR), after the Congo (Kinshasa) and Botswana (26% and 23% respectively). 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

Argyle (WA): A 2.2 km exploratory decline to 300 m depth is being developed to test the fragmentation and 'caveability' of the ore body below the open pit as part of a full feasibility study (costing \$70 million) to assess the viability of underground mining after the open pit reserves are exhausted in 2008. A decision on the underground mine development option is expected in 2005.

Merlin (NT): Mining ceased in the second quarter of 2003 ending five years of operations. A total of 468 000 carats was produced at Merlin, mostly from the four southern pipes – Excalibur, Launfal, Palomides and Sacramore. The diamonds were mostly of gem quality with an average value of US\$100 per carat and included the largest diamond found to date in Australia, a 104.73 carats gem named Jungiila Bunajina after the traditional owners of the region. Following an unsuccessful tendering process to sell the Merlin deposit, Rio Tinto Ltd closed and rehabilitated the mine in the second half of 2003. In September 2003, Striker Resources acquired the exploration tenements around the Merlin mine in an arrangement that includes access to Rio's Kimberley diamond database.

Ellendale (WA): Kimberley Diamond Company Ltd reported that production from Pipe 9 continued to yield diamonds of very high quality with some sales in excess of US\$200 per carat. Production is scheduled to increase in the second half of 2004 with the commissioning of a larger (2.2 Mtpa) plant. Long term intentions are to increase to 8.8 Mtpa producing 400 000 carats per annum by 2006 making it one of the world's five largest producers.

Seppelt (WA): A pilot HMS treatment facility was deployed at the Seppelt 2 site late in 2003 to treat a trial sample of approximately 20 000 t of near surface kimberlite and infill material at a rate of up to 30 t/hour. The trial is expected to recover in excess of 15 000 carats of diamonds totalling around \$1 million in value. It will provide mineral processing information and run-of-mine diamond value that will be input to the decision on the possible development of an open-pit operation. The pit would exploit the high-grade 2 cpt weathered kimberlite, which underlies the lower grade infill gravels.

Gold

Gold has a range of uses but the two principal applications are as an investment instrument and in the manufacture of jewellery. Secondary uses, in terms of the amount of gold consumed, are in electronic and dental applications.

Gold prices maintained the higher levels attained in 2002 through much of 2003 before a further increase over the last few months resulted in the year-end price exceeding US\$400/oz. The continuing stronger price contributed to an increase in spending on exploration for gold. Increased gold output in 2003 arrested the downward trend that started after the record production in 1997. In 2003 gold contributed over \$5.5 billion to the Australian economy in export earnings.

Resources

Australia's gold resources occur and are mined in all States and the Northern Territory.

In 2003 EDR, which fell by 33 t (1 Moz), accounted for 78% of total demonstrated resources. EDR increased in Queensland, New South Wales, Victoria and South Australia. Western Australia's EDR, which is almost 62% of the national total, fell by 47 t (1.4%) to 3287 t in 2003. South Australia had the second largest EDR. In the Northern Territory, EDR fell by 42 t to 180 t. Only minor variations were recorded in the other States.

Subeconomic demonstrated resources rose by 274 t in 2003. All the growth was in the paramarginal category, which increased by 280 t to 1437 t. Western Australian paramarginal resources rose by 295 t to 1115 t which was 78% of total paramarginal resources. Increases also occurred in Victoria, South Australia and Tasmania. The submarginal demonstrated resources fell by six t to 107 t, over half of which is in Western Australia.

Inferred resources rose by 110 t (4%) but the increase was insufficient to offset the large reduction (323 t) that occurred in 2002. Inferred resources grew strongly in Western Australia (up 104 t) and New South Wales (up 48 t) and minor increases were recorded for Tasmania and South Australia. Western Australia dominates inferred resources accounting for 56% of the total, a slightly higher proportion than in 2002 but well under the 62% held in 2001.

The ratio of demonstrated to inferred resources remained steady at 2.4:1 in 2003. The level of this ratio continues to be of concern. It indicates that the availability of inferred resources that may be upgraded by future exploration to the potentially mineable categories is relatively limited.

Accessible EDR

EDR for gold are essentially unencumbered (less than a fraction of 1% is in any form of restricted area). At Australia's 2003 rate of production, EDR is sufficient for an average 19 years production. If, however, resources only classified as reserves under the JORC Code are considered, they will support only 12 years at the 2003 production rate. This is one year lower than the 2002 figure. It should be remembered that these are average figures and that there are some operations that may continue after the 19 or 12 year periods and there are others that will close before the end of those periods. These figures clearly illustrate the need for ongoing successful exploration in both the short and medium terms.

JORC Reserves

EDR is the sum of the JORC Code reserves categories plus those resources from the measured and indicated resource categories assessed by Geoscience Australia as likely to be economic. In 2003 just under 64% of EDR fell into the JORC reserves category compared to 66% in 2002.

Exploration

In the 2002–03 financial year, gold continued to dominate mineral exploration spending with \$378 million (51.7%) of total exploration in the financial year. In real terms (2002–03\$) this was the first year-on-year increase since the peak year of 1996–97 but the total was still less than half the level attained in that year.

For the calendar year 2003 (based on the sum of ABS data for the four quarters of 2003) gold exploration expenditure was \$373.7 million, \$18.5 million (5%) higher than 2002. It was 51% of total exploration spending. Although Western Australia dominated exploration by attracting \$260.1 million (70%), work was carried out in the other regions, all with encouraging results. Selected highlights which are indicative of the year's activity are reported at the end of this section.

Data published by the Metals Economics Group (MEG) (a Canadian company) on company exploration budgets indicates that intended spending on gold exploration in Australia for the year was US\$209.3 million (A\$338 million using the exchange rate used by MEG). The higher amount reported by ABS may well have been a response to the continued strength of the gold price over the year.

The MEG data show that 47% of gold exploration budgets were expected to be directed at grassroots exploration, 24.2% at late stage and feasibility study stage, and 28.4% on minesite exploration.

Although gold exploration spending had been adversely effected by the global mergers and acquisitions activity in recent years and the low gold price, there are continuing signs that the worst of this impact has passed and that companies are undertaking significant exploration programs.

New gold mineralisation was found across the continent and at depth below known deposits. A variety of styles of mineralisation also continued to be found. The Archaean greenstones of Yilgarn Craton

(WA) remain a very favourable target, but the reported results that follow suggest that substantial opportunities exist in other provinces.

NEW SOUTH WALES

- Continuing exploration by Alkane Exploration Ltd at its **Wyoming** prospect, 12 km north of its Peak Hill mine yielded numerous high grade intersections. At Wyoming One, intersections included 129 m at 3.85 g/t Au from 48 m, 15 m at 11.92 g/t Au from 105 m and 99 m at 4.3 g/t Au from 258 m; and at Wyoming Three, 7 m at 5.17 g/t Au from 47 m and 10 m at 8.35 g/t Au from 48 m. Alkane released an initial resource estimate for Wyoming One and Wyoming Three of 6.38 Mt at 2.43 g/t Au for a contained 0.498 Moz.
- Near Cobar, Golden Cross Resources Ltd reported encouraging results from an initial drilling program at the **Mt Boppy South** prospect. The holes tested an epithermal vein system and yielded best results including 3 m at 10.8 g/t Au from 24 m, 10 m at 2.75 g/t from 9 m, and 4 m at 3.29 g/t Au from 14 m.
- At **Canbelego**, Golden Cross Resources Ltd reported encouraging intersections including 8 m at 5.26 g/t Au from surface, 5 m at 4.98 g/t Au from 30 m, and 2 m at 2.5 g/t Au from 5 m.
- Central West Gold NL reported high grade intersections from the **Boorook** prospect near Tenterfield. These were 3 m at 103 g/t Au, and 2 m at 22 g/t Au in holes 100 m apart.

NORTHERN TERRITORY

- At the **Malbec** prospect, 1 km west of its Chariot mine near Tennant Creek, Giants Reef Mining Ltd announced significant gold intersections in non-magnetic ironstones. These included 15 m at 7.83 g/t Au from 9 m, 1 m at 10.95 g/t Au from 49 m, and 1 m at 14.36 g/t Au from 54 m.
- Northern Gold and partner Harmony Gold reported several high-grade drill intersections at the **Zapopan** project near Pine Creek including 3.6 m at 35.7 g/t Au, 6 m at 31.2 g/t Au and 5.7 m at 19.4 g/t Au, all closely approximating true width.

QUEENSLAND

- Strategic Minerals Corporation NL continued to report high grade intersections from the **Explorer** prospect, part of its Woolgar project, 100 km north of Richmond. Results included 8 m at 10.7 g/t Au from 113 m, and 11 m at 14.7 g/t Au from 82 m. At **Explorer South** some exceptional intersections were reported including 1 m at 84.92 g/t Au from 51 m, and 1 m at 83.7 g/t Au from 52 m both of which occur in a broader band of mineralisation of 9 m at 21.66 g/t Au.
- At **Wallace South**, 20 km southeast of Cloncurry, a resource of 52 000 oz from 0.66 Mt at 2.4 g/t Au was estimated by Cloncurry Mining Co. Better drill results include 40 m at 3.09 g/t Au, 10 m at 13.44 g/t Au and 16 m at 8.49 g/t Au.

SOUTH AUSTRALIA

- Helix Resources Ltd continued to report encouraging intersections from the **Tunkillia** project in the Gawler Craton. These included 29 m at 4.3 g/t Au, 2 m at 29.7 g/t Au, and 2 m at 27.8 g/t Au from one hole in the Area 223 North area.
- At its **Challenger** mine, Dominion Mining Ltd reported drilling had demonstrated the potential for an extended underground mine life by intersecting mineable grade mineralisation over 150 m vertically below previous drilling. Intersections reported included 4 m at 22.03 g/t Au, 6 m at 21.5 g/t Au, and 6 m at 42.48 g/t Au.

TASMANIA

- At the **Lisle** project, TasGold Ltd reported high-grade gold intersections. Some of the better results included 1 m at 5.8 g/t Au, 1 m at 7.8 g/t Au, and 4 m at 12.8 g/t Au from 6 m, including 1 m at 42.7 g/t Au from 7 m.

VICTORIA

- MPI Mines Ltd reported two significant gold discoveries in basement rocks below sediments of the Murray Basin to the north of its Stawell gold mine. At **Kewell**, 100 km northwest of Stawell, under 120 m of cover, Stawell style mineralisation was intersected with intercepts of 4.2 m at 3.46 g/t Au from 149.6 m, 2.3 m at 2.2 g/t Au from 161.6 m, and 4.12 m at 12.6 g/t Au from 180.44 m reported. At **Wildwood**, 20 km north of the Stawell mine and also under cover, MPI intersected 4 m at 5.21 g/t Au from 119.8 m and 3.45 m at 3.84 g/t Au from 131.7 m.
- At its **Ballarat East** project at Ballarat, Ballarat Goldfields NL reported an indicated resource of 0.3 Mt at 9.2 g/t Au (0.1 Moz) and an inferred resource of 1.7 Mt at 11 g/t Au (0.6 Moz). Recent drilling returned high grade intersections including 2.4 m at 14.1 g/t Au from 602 m, and 6.7 m at 9.6 g/t Au from 599 m.
- AGD Mining Ltd reported very encouraging drill results from its **Augusta** project 45 km east of Bendigo. The intersections were 1 m at 29.6 g/t Au from 32.8 m, 0.32 m at 49.4 g/t Au from 30.15 m, and 0.22 m at 36.1 g/t Au from 20.1 m.

WESTERN AUSTRALIA

- Drilling by AngloGold Ltd identified the Carey Shear, a repetition of the Sunrise Shear Zone, at a depth of approximately 900 m under the **Sunrise Dam** mine. The hole also intersected 10 m at 53.6 g/t Au at a downhole depth of 1350 m.
- Gindalbie Gold NL reported a high-grade discovery at the **Bobby McGee** prospect some 160 km southwest of Mount Magnet. Intersections reported include 7 m at 171 g/t Au from 37 m, 16 m at 6.97 g/t Au from 24 m, and 4 m at 8.7 g/t Au from 13 m.
- At the **Firegold** prospect, in the Ashburton province, 17 km northwest of the Mt Olympus gold mine, Pelican Resources Ltd reported highly encouraging drill results including 1 m at 21.8 g/t Au from 35 m, 2 m at 3.51 g/t Au from 38 m, and 17 m at 1.02 g/t Au from 20 m including 6 m at 2.08 g/t Au.
- Wide zones of gold mineralisation were reported by De Grey Mining Ltd from reconnaissance drilling at the Indee Turner River gold project, 70 km southwest of Port Hedland. Among the intersections reported were 32 m at 8.40 g/t Au, 26 m at 8.39 g/t Au, and 40 m at 4.34 g/t Au at the **Wingina Well** prospect.
- Results of drilling undertaken at the **Frog's Leg** project, near Kalgoorlie, to assist in a feasibility study for an underground mining operation proved encouraging. Dioro Exploration NL reported intersections including 9 m at 5.03 g/t from 200 m, 9 m at 5.44 g/t Au from 135 m, and 11 m at 6.14 g/t Au from 236 m.
- At the **Minjar** project, 150 km southwest of Mount Magnet, Gindalbie Gold NL reported high-grade gold intersections from beneath the planned base of the Silverstone open pit. Results included 5 m at 15.72 g/t Au, 11 m at 12.0 g/t Au, and 6 m at 15.46 g/t Au.
- At the **Wallbrook** project, 125 km northeast of Kalgoorlie, Jackson Gold Ltd reported several high grade intersections. On the Redbrook prospect it encountered 120 m at 1.27 g/t Au – the entire length of hole. Other intersections reported from the project included 1 m at 9.36 g/t Au at the Painted Harlot prospect, and 7 m at 9.45 g/t Au at the Eleven Bells prospect.
- Dalrymple Resources NL reported that a program of drilling aimed at testing the underground potential of the **Thunderbox** deposit in Western Australia returned intersections including 98.74 m at 2.74 g/t Au and 56.26 m at 2.38 g/t Au.
- East of Laverton, AngloGold Ltd and Independence Gold Ltd intersected promising gold values at the **Tropicana East** project. Limited drilling returned intersections of 13 m at 1.9 g/t Au from 79 m, and 11 m at 1.3 g/t Au from 43 m in a second hole.

- At Cullen Resources Ltd's **Gunbarrel** project some 130 km east of Wiluna, high grade gold intersections were recorded from the Southern Prospect. These included 1 m at 77.7 g/t Au from 56 m, 8 m at 4.28 g/t Au from 86 m, and 1 m at 11.94 g/t Au from 8 m.
- Drilling at the **Midway** prospect, Mt Gibson project, 280 km northeast of Perth, by Oroya Mining Ltd yielded a number of significant intersections including 4 m at 9.22 g/t Au from 42m, 13 m at 8.97 g/t Au from 74 m, and 21 m at 3.35 g/t Au from 49 m.
- Hamill Resources Ltd continued to report deep high grade intersections at its **Baldock** prospect near Menzies. These included 1.36 m at 74.8 g/t Au from 241 m, 3.43 m at 40.6 g/t Au from 226 m, and 1.16 m at 59.6 g/t Au from 339.7 m.
- At the **Wilthorpe** project, 120 km north of Meekatharra, Image Resources NL reported encouraging results which included 13 m at 1.4 g/t Au from 35 m, 3 m at 13.1 g/t Au from 3 m, and 2 m at 4.7 g/t Au from 50 m.
- Deep intersections were reported by Austminex NL from the **Dreadnought** prospect 5 km south of Coolgardie. Dreadnought currently has an inferred resource of 0.97 Mt at 3.0 g/t Au and the new results have the potential to increase that. Results include 14 m at 9.1 g/t Au from 177 m, 12 m at 10.7 g/t Au from 100 m, and 7 m at 9.4 g/t Au from 152 m.
- Helix Resources Ltd reported high grade intersections from the **Apollo** deposit at its Glenburgh project in the Gascoyne region. Results include 6 m at 20.5 g/t Au from 74 m, 4 m at 6.3 g/t Au from 97 m, and 3 m at 2.9 g/t Au from 162 m.
- Mawson West Ltd reported encouraging high grade intersections from its **Maybell** prospect at Norseman. The better intersections reported included 6 m at 31.42 g/t Au which included 1.5 m at 109.61 g/t Au, and 5.5 m at 15.66 g/t Au.
- Hampton Hill Mining NL announced high grade intersections from its **Apollo Hill** prospect, 45 km southeast of Leonora. Better intersections included 7 m at 3.9 g/t Au including 2 m at 12.1 g/t Au, 3.5 m at 7.2 g/t Au including 0.4 m at 55.6 g/t Au, and 9.5 m at 4.5 g/t Au including 0.4 m at 85.0 g/t Au.
- A new gold discovery was announced at the **Jenkinson Well** project, about 15 km southwest of Laverton. The project, a joint venture between Avoca Resources (30%), Placer Dome Inc (35%) and Metex Resources Ltd (35%), returned an initial drill intersection of 8 m at 8.81 g/t Au from 104 m.
- Joint venturers Newmont Australia Ltd and Johnsons Well Mining NL reported that at the **Moolart Well** project 150 km north of Laverton, gold mineralisation had been defined over about 4 km. Better intersections included 12 m at 6.47 g/t Au, and 16 m at 1.25 g/t Au.

Copper-Gold

- At **Prominent Hill**, SA, Minotaur Resources Ltd continued to report good intersections including 130 m at 1.41% Cu and 0.43 g/t Au, and 162 m at 1.03% Cu and 0.46 g/t Au. Late in the year further intersections reported included 103 m at 2.52% Cu and 1.1 g/t Au, and 133 m at 1.72% Cu and 1.4 g/t Au including 27 m at 4.2% Cu and 2.3 g/t Au. This drilling confirmed the presence of two copper-bearing breccias in the western part of the deposit of which the southern breccia is of higher grade and wider than the northern one.
- Drilling by Triako Resources Ltd at its **Iodide South** prospect at Mineral Hill, NSW, returned intersections including 8.2 m at 12.4% Cu and 1.2 g/t Au, 14.6 m at 1.5% Cu and 6.2 g/t Au including 4.5 m at 2.1% Cu and 15.8 g/t Au, and 5.6 m at 1.4% Cu and 3.2 g/t Au.
- Exploration by Newcrest Mining Ltd below the **Ridgeway** mine (Ridgeway Deeps) and in the Cadia Far East area, NSW, continues to expand the resource base of the Cadia Valley Operations, for example, an intersection of 408 m (not true width) at 2.98 g/t Au and 0.71% Cu was made at the Ridgeway Deeps drilling.

- Newcrest has also identified a large porphyry-style system at **Gooley's North** prospect on the Junction Reefs Joint Venture area, east of Cadia, NSW, where an intersection of 743.4 m at 0.17 g/t Au and 0.10% Cu was obtained early in 2003.
- Newcrest, and its joint venture partner Compass Resources, has discovered a new porphyry system at **Buryon** near Alectown, northwest of Bathurst, NSW, where 196 m at 0.26% Cu and 0.16g/t Au was intersected.
- Cloncurry Mining Company reported an inferred resource of 0.875 Mt at 1.65% Cu and 1.0 g/t Au at the **Kangaroo Rat** prospect, about 20 km southeast of Cloncurry, Qld. Better drill results include 9 m at 4.6% Cu and 0.98 g/t Au, 6 m at 3.1% Cu and 2.1 g/t Au, and 11.2 m at 2.14% Cu and 1.4 g/t Au.

Production

Australian gold production reported by ABARE for 2003 was 282 t an increase of 15.86 t on 2002 production. The Super Pit at Kalgoorlie in Western Australia was the largest producer with an output of nearly 0.9 Moz. In 2003 Western Australia dominated Australian production with 190 t which was two-thirds of total Australian output (Table 2).

TABLE 2. Australian gold production 1999 to 2003. (Source: ABARE Australian Commodity Statistics 2003 and ABARE Australian Mineral Statistics September Quarter 2004).

	1999 (t)	2000 (t)	2001 (t)	2002 (t)	2003 (t)
New South Wales	21.04	18.58	17.10	23.48	27
Victoria	4.63	4.23	3.50	3.24	4
Queensland	34.15	37.01	31.89	25.06	26
South Australia	1.77	2.95	4.31	3.14	5
Western Australia	210.92	203.74	196.59	187.20	188
Tasmania	4.95	6.68	6.18	6.05	10
Northern Territory	22.29	23.14	20.51	17.95	24
Australia	299.75	296.41	280.08	266.14	282*

* differences in totals are due to rounding.

ABARE's longer-term outlook is for gold production to rise to 345 t in 2008–09. The outlook for future production is reliant on new mines coming on stream especially large operations such as the proposed Boddington, Telfer (both WA) and Cowal (NSW) mines. Smaller mines such as operations at Chariot (NT) and Frog's Leg (WA) will play important roles in maintaining existing production levels.

World Ranking

The USGS estimate of world gold reserves of 43 000 t was similar to the 2002 estimate. According to the USGS, South Africa still has the world's largest reserve of gold at 8000 t (18.6%) the same level as in 2002. The USA was still ranked second with 13.0% and Australia third with 11.8%.

The USGS estimate world mine production of gold was 2619 t in 2003. South Africa with 17.2% of world production remained the leading producer with an output of 450 t, 51 t higher than in 2002. It was followed by the USA which had an estimated production of 285 t (298 t in 2002), which was 10.9 % of world output. Australia had a similar output and share to the USA. Then followed China (195 t), Russia (180 t), Indonesia (175 t) and Canada (165 t).

Industry Developments

Newcrest Mining Ltd was well advanced on the development of its new gold-copper operation at **Telfer**, WA, which currently has an expected life of 24 years. The \$976 million Stage One project will include development of the open pit, construction of the concentrator and other necessary



Exploration drilling for gold in the Cracow region, Queensland.
(Newcrest Mining Ltd)

infrastructure. The \$215 million Stage Two will be the underground mine development. Over the life of the mine annual output is expected to be 0.8 Moz of gold and 28 000 t copper. By the end of 2003 construction was on schedule and budget.

Barrick Gold's **Cowal** project, near West Wyalong, NSW, with a reserve of 66.4 Mt at 1.18 g/t Au (2.8 Moz), received approval to proceed to develop the open-pit project. Production is expected to average 270 000 oz/annum over the first decade. The company was granted a Mining Lease in June 2003 and work is on target for the first production in 2006.

Giants Reef Mining poured the first gold from its **Chariot** project near Tennant Creek, NT. The operation will mine 125 000 tpa of ore and produce around 60 000 oz/annum of gold at cash costs of around A\$230/oz, with current reserves giving it a four-year mine life. Also in the Northern Territory, Renison Consolidated Mines NL reported that the first gold from its **Quest 29** mine near Pine Creek was poured in September 2003.

Newcrest Mining Ltd and Sedimentary Holdings Ltd signed the mining joint venture documents allowing the start of construction of the Cracow gold project 2 km west of **Cracow**, Qld. The capital cost of the project is A\$89 million, and the first gold production is expected in December 2004.

Dominion Mining Ltd announced that it will proceed with the development of an underground mine at its **Challenger** gold project in the Gawler Craton, SA, where open cut production commenced in 2002. Subject to gaining regulatory approvals development is scheduled for March 2004, with the first ore to be reached in September 2004.

Perseverance Corp Ltd completed a bankable feasibility study into the development and mining of the sulphide resources at **Fosterville** near Bendigo, Vic. The A\$75 million project will include open-pit and underground mines and a treatment plant with an annual capacity to mine and treat 800 000 t of refractory ore. Production is planned to start in the December quarter 2004.

The Laverton Exploration JV (Metex Resources Ltd and Granny Smith Mines Ltd, a wholly-owned subsidiary of Placer Dome Asia Pacific Ltd) announced that it would undertake a trial mining programme at the **Whisper** deposit near Laverton, WA. The programme aims to extract 100 000 t of ore at a grade of 3.1 g/t Au, to be processed through the Granny Smith plant.

Iron Ore

Iron constitutes about 5% of the Earth's crust and is the fourth most abundant element after oxygen, silicon and aluminium. Almost 300 minerals contain iron as an essential constituent, however, only a few are mined for industrial purposes. Those exploited are mainly the iron oxide minerals of hematite, magnetite, goethite and limonite. About 98% of iron ore is used in the iron and steel industry with the residual being used in cement manufacturing, heavy medium applications, pigments, high density concrete and animal feed additives.

The iron ore industry in Australia is dominated by the Pilbara operations of Hamersley Iron and BHP Billiton in Western Australia. Other mines operate at Koolyanobbing and Cockatoo Island (WA), Middleback Ranges (SA) and Savage River (Tas). During 2003 four new mines commenced, namely, Mining Area C (MAC), Talling Peak, Windarling and Mount Jackson, all in Western Australia. Minor production of iron ore for non-steel industry use occurs at Breadalbane and Tallawang in New South Wales and Kara in Tasmania.

Resources

In 2003, EDR decreased by 4.6% to 12.4 Gt mainly due to production and revised reserve statements by BHP Billiton and Hamersley Iron. Newly reported resources at Koolan Island and Cockatoo Island were included for the first time. Western Australia has over 99% of Australia's EDR with about 94% occurring in the Pilbara district.

There was a 7.0% increase in paramarginal demonstrated resources (PDR) to 1.2 Gt after Portman Ltd released a new reserve statement in early 2004. SDR increased by 2.6% to 1.9 Gt due to new resources being announced at a number of deposits. Inferred resources increased by 7.4% due to upgraded resources by BHP Billiton and Hamersley Iron and 12 new deposits being added. Western Australia has about 88% of Australia's total identified resources of iron ore with 80% occurring in the Pilbara district.

Accessible EDR

Almost all EDR is accessible except for the remaining resource at Orebody 23 (18 Mt) in the Newman District of Western Australia which is inaccessible because of environmental reasons. The resource life of the accessible EDR of 12.4 Gt is around 60 years.

JORC Reserves

About 35% of accessible EDR, or 4.3 Gt, is in JORC reserve categories. The resource life of accessible JORC reserves is about 20 years.

Exploration

ABS data indicate that exploration expenditure for iron ore in 2003 totalled \$52.1 million an increase from \$37 million in 2002. Detailed data on spending is not available from ABS but almost all is likely to have been spent in Western Australia. Low levels of exploration occurred in Northern Territory, Tasmania and South Australia.

Production

ABARE reported that Australia's iron ore production in 2003 was 212.9 Mt (182.7 Mt in 2002) with 97% produced in Western Australia. The remaining production came mainly from South Australia and Tasmania. Exports in 2003 totalled 187.3 Mt (167.3 Mt in 2002) with a value of \$5100 million. The combined iron ore and iron and steel exports accounted for 6.3% of Australia's total merchandise export revenue. ABARE has forecast that Australia's iron ore production will reach 267 Mt in 2009.

World Ranking

Australia has some 9% of world EDR of iron ore and is ranked fourth after Ukraine (21%), Russia (17%) and China (15%). In terms of contained iron, Australia has about 11% of the world's EDR and is ranked third behind Russia (21%) and Ukraine (14%).

Australia produces around 18% of the world's iron ore production and is ranked third behind China (21%) and Brazil (19%).

Industry Developments

Hamersley Iron (100% Rio Tinto): In December 2003 Hamersley Iron announced plans to spend \$1.25 billion expanding the **Port of Dampier** (\$945 million) and the **Yandicoogina** mine (\$270 million) in the Pilbara region and rail upgrading (\$35 million). The port expansion will boost iron ore capacity from 74 to 116 Mtpa and output at Yandicoogina will rise from 24 to 36 Mtpa. The Yandicoogina expansion is due for completion in early 2005 and the port expansion is scheduled to be commissioned in late 2005. During 2003, the Yandicoogina mine was expanded from 20 to 24 Mtpa.

Brockman No. 2, 60 km NW of Mount Tom Price, was placed under care-and-maintenance in 2002 while a major upgrade of the operation was undertaken. The mine reopened in 2003 with a capacity of 8 Mtpa. The **Eastern Range** mine, 10 km east of the Paraburdoo mine, is scheduled to commence in 2004 as a replacement for the depleted Paraburdoo orebodies. At Marandoo, 40 km NE of Mount Tom Price, investigations are being undertaken into future mining areas to the north and east of the current mining operation.

Robe River Associates (53% Rio Tinto): During 2003 Rio Tinto and Robe River Associates agreed to ship ore from Rio's wholly owned **Yandicoogina** mine through Robe's Cape Lambert port facilities. The first iron ore from the Yandicoogina mine was shipped from Cape Lambert in October 2003. In January 2004, Rio Tinto and Robe River Associates agreed to form a new entity referred to as **Pilbara Iron** which will be responsible for operating and maintaining all of Hamersley Iron's and Robe's rail, port, power and non-infrastructure assets as well as providing corporate and site services.

In December 2003, Robe River Associates announced a US\$105 million expansion of the **West Angelas** mine to a nominal capacity of 25 Mtpa. Work on the expansion is expected to commence in early 2004 and commissioning is due by mid-2005. The mine was commissioned in 2002 and is scheduled to be producing 20 Mtpa during the first half of 2004.

BHP Billiton: The **Mining Area C (MAC)** project located 120 km NW of Newman in the Pilbara region of Western Australia was officially opened on 30 October 2003. The US\$213 million project was commissioned ahead of schedule and consists of a mine, processing plant, 38 km rail spur and associated infrastructure with a capacity of 15 Mtpa. The first Marra Mamba ore was railed to Nelson Point on 16 August and the first shipment departed on 24 September 2003. MAC production is scheduled to ramp-up to 15 Mtpa by 2005.

The **Products and Capacity Expansion (PACE)** project continued during 2003 and is scheduled for commissioning in the first half of 2004. The US\$351 million project will expand BHP Billiton's rail and port facilities in the Pilbara from 85 to 100 Mtpa. Feasibility studies are being undertaken for a further expansion to 120 Mtpa should the market warrant additional capacity.

The US\$27 million Iowa project at the **Yandi** mine is scheduled to be completed in early 2004. Work includes upgrading ore handling facilities and installing a 5.3 km long overland conveyor. The conveyor is designed to reduce ore haulage costs as trucking distances lengthen for some of the Yandi pits. The upgrade will raise the operations capacity 3 Mtpa to 42 Mtpa.

Portman Ltd: The **Koolyanobbing** expansion project received State and Federal Government approvals during 2003. Environmental approvals included a condition that no more than 30% of the native plant *Tetratheca Paynterae* was directly impacted by mining at Windarling.



Mining Area C iron ore project, Pilbara Region of Western Australia.
(BHP Billiton Iron Ore)

The \$20.3 million expansion project commenced in late 2003 and involves the development of mining areas at **Windarling** and **Mount Jackson**. Ore will be trucked to the existing processing plant for blending to extend the life of the operation and increase production. First ore is scheduled to be delivered to Koolyanobbing in March 2004.

From August to November, development drilling was undertaken that led to the finalisation of a mine optimisation study in December 2003. In early 2004 Portman announced that the Koolyanobbing project had a life of 13 years at a production rate of 5 Mtpa. Portman plan to spend \$5 million on an exploration program aimed at increasing the long term production level.

At **Cockatoo Island** there were difficulties associated with mine dewatering and construction of the Stage 2 seawall and construction was suspended in mid-2003. Dewatering and geotechnical studies were undertaken and construction of the Stage 2 seawall was due to recommence in early 2004. The current reserves of 3.1 Mt will support production for three years.

Mount Gibson Iron Ltd: The \$20 million **Tallering Peak** mine commenced in October 2003 at a rate of 1.6 Mtpa over 10 years. Road, rail and port infrastructure was completed in late 2003 and railing of iron ore to Geraldton is planned to commence in early 2004. Infrastructure developments included a \$100 million dredging of Geraldton harbour to accommodate 60 kt Panamax vessels and the construction of a 150 kt capacity storage shed.

The company plans to spend \$10 million to develop a mine at the **Mount Gibson** deposit during 2005. Planned production is at a rate of 1.5 Mtpa over 10 years. Other proposals include supplying magnetite concentrates to China from Tallering Peak, Mount Gibson or Koolanooka South.

Aztec Resources Ltd: The **Koolan Island** deposits are located in Yampi Sound about 130 km NW of Derby in Western Australia. BHP mined 67 Mt of high grade ore between 1965 and 1993. In 2003 Aztec announced 25 million tonnes of ore grading 67% iron in the Main orebody. Aztec plans to complete a feasibility study during 2004 with a \$50 million redevelopment proposed to commence

in 2005. A drilling program planned for 2004 will test extensions of the Main orebody and other satellite orebodies.

Hope Downs Management Services: The \$1.5 billion **Hope Downs** project consists of constructing mine, rail and port infrastructure based on the Hope Downs 1 Marra Mamba deposit 100 km NW of Newman. Commencement of production is planned for 2007 at a rate of 5 Mtpa increasing to 25 Mtpa within five years. There is potential for a \$300 million saving if agreement can be reached with BHP Billiton for access to the existing rail network.

Fortescue Mining Group Ltd: Propose to spend \$1.2 billion constructing common access infrastructure in the Pilbara region of Western Australia including a 400 km rail line and loading berths at Port Hedland. The company also plans to develop a 20 Mtpa operation at **Mount Nicholas, Tongololo Creek, Mount Lewin** and/or **Mindy Mindy**. Geological work and reverse circulation drilling commenced on Mount Nicholas and Mindy Mindy in the second half of 2003.

Midwest Corporation Ltd: Plan to develop a 1.0 Mtpa direct shipping ore project from high grade resources at Koolanooka and Blue Hills commencing in late 2004. This would be followed by a \$540 million 4.5 Mtpa pellet plant operation based on the magnetite deposit at Koolanooka located 120 km SE of Geraldton. Midwest also completed a conceptual study of developing a 10 Mtpa direct shipping iron ore project at Weld Range located 270 km NE of Geraldton.

A drilling program at **Koolanooka** and **Blue Hills** was completed in the last quarter of 2003. Further drilling and geological work is planned for Blue Hills, **Weld Range** and Jack Hills in the first quarter of 2004. High grade direct shipping ore was mined at Koolanooka between 1966 and 1973.

Grange Resources Ltd: The **Southdown** deposit is located 80 km NE of Albany in Western Australia. Grange proposes to produce 2.0 Mtpa of magnetite concentrate over a 14 year period. A detailed review of the Southdown project is being undertaken to assess the viability.

Mineralogy Pty Ltd: Mineralogy is promoting two projects:

- The **Austeel** consortium is proposing an Electric Arc Furnace (EAF) project based on the Fortescue magnetite deposits located 80 km SW of Karratha in Western Australia. The \$3 billion project consists of a mine, concentration and pelletising plants and direct reduction and briquetting of iron ore. The EAF steelmaking plant is proposed to be located in Newcastle, NSW. The project received environmental approvals in October 2003.
- **International Minerals Pty Ltd** is proposing to mine and export pellets from the Fortescue magnetite deposits.

OneSteel Ltd: In April 2003 OneSteel signed a six-year contract with **Henry Walker Eltin** that covered mining, crushing and train loading services and a five-year ore beneficiation project for the **Middleback Range** operation in South Australia. The project will process 9 Mt of low grade ore to produce 5 Mt of useable high grade ore and is scheduled to be commissioned in mid-2004.

In mid-2003 OneSteel announced a \$6 million feasibility study into magnetite resources in the Middleback Ranges. If the resources are found to be commercial there is potential to slash up to 5% off steelmaking costs. The study would also assess the marketability of the current hematite ore. OneSteel plan to use **Portman Ltd** to market any bulk iron ore and iron ore pellets from Whyalla.

Ivanhoe Mines Ltd: At **Savage River** on the west coast of Tasmania the current open-cut mining operations are scheduled to terminate at the end of 2007 and the pellet producing operations are scheduled to terminate in 2009. Ivanhoe is undertaking a pre-feasibility study of an underground block caving operation under the North Pit.

Arafura Resources NL: Entered into an agreement with **Territory Iron Pty Ltd** which allows Territory to develop, mine and sell iron ore located at Arafura's **Frances Creek** property located 200 km SE of Darwin. During 2003 Territory Iron completed a detailed gravity survey over the area and plans to carry out further definition of known resources and exploration for new resources in 2004. The Frances Creek mine produced 8 Mt of iron ore grading 59% Fe between 1966 and 1974.

Operating and proposed **Direct Reduced Iron** (DRI) and steelworks in Australia include:

- DRI is produced by **BHP Billiton** from its **Boodarie** hot briquetted iron (HBI) plant near Port Hedland in Western Australia.
- A \$420 million Hismelt DRI processing plant commenced construction in January 2003 at **Kwinana** in Western Australia. When commissioned in late 2004 the plant will process 1.3 Mtpa of iron ore to produce 800 ktpa of 96% iron content pig iron.
- Pig iron is produced in blast furnaces at **Port Kembla** and **Whyalla**.
- **Felix Resources Pty Ltd** has divested the Whyalla pig iron demonstration plant to **Ausmelt Ltd**. The demonstration plant is under care-and-maintenance. Felix's **Yarrabee** coal mine in Central Queensland won a three year contract to supply Pulverised Coal Injection (PCI) coal to the Hismelt project.
- Steel is produced at **Port Kembla**, **Whyalla**, **Rooty Hill**, Mayfield and **Laverton North**.
- **Compact Steel** is planning a 1.4 Mtpa steel plant costing \$1.5 billion at **Rockingham** in Western Australia.
- **Austeel** has a proposal for a mine and HBI plant in the Pilbara with an electric arc furnace in the Newcastle District.
- **Protech Steel** is investigating a \$600 million steel processing mill to produce mainly coated steel products in **Newcastle**.
- **Hunter Specialty Steels** propose to construct a steel mini-mill capable of producing up to 260 000 tpa of stainless and specialty steel products in the Hunter Valley of New South Wales.
- **Westralia Iron and Steel Corporation Ltd** is proposing a 1.5 Mtpa pig iron plant for **Collie** in Western Australia.

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. Lithium products from Greenbushes have a range of uses including production of specialty glasses, ceramics and ceramic glazes, glass bottles. The ore (predominantly spodumene $\text{Li}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2$) is also a feedstock for the production of lithium carbonate in the chemical industry.

Resources

All of Australia's lithium resources occur in the Greenbushes deposit, in the southwest of Western Australia. There was an increase in EDR in 2003 to just over 167 000 t, due mainly to a reassessment of resources. Greenbushes is the world's largest and highest grade spodumene deposit.

Subeconomic resources decreased by 23% as a result of resource reassessment. Inferred resources remained unchanged.

Accessible EDR

All EDR is accessible for mining.

JORC Reserves

EDR is the sum of the JORC Code reserves categories plus those resources from the measured and indicated resource categories assessed by Geoscience Australia as likely to be economic. In 2003, 87% of EDR are in JORC reserves categories.

Exploration

There are no statistics available on exploration expenditure for lithium. With large world resources of lithium, particularly in the form of lithium-rich brines mainly from Chile, as well as increased resources at the Greenbushes deposit, it is very unlikely that there will be any substantial exploration expenditure for lithium in Australia in the near future.

Production

Sons of Gwalia Ltd remained the world's largest producer of lithium minerals in 2003. Production for the year was 120 536 t of spodumene (3.5 kt Li), an increase of almost 10% over 2002, while sales of lithium minerals increased by 21%. This improvement in sales reflected the continued recovery in some niche markets within the lithium industry. However, the increased supply of lithium carbonate from brine operations in Chile and Argentina is continuing to have an impact on the price of lithium minerals on world markets.

World Ranking

According to estimates published by the USGS, Chile holds approximately 73% of the world's lithium resources, followed by China 13%, Canada 4.5% and Australia with just over 4%. 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 dominant feedstock for lithium carbonate production, are produced mainly by Chile. Canada and Australia have the most significant hard-rock resources of lithium.

World production in 2003 was estimated from GA and USGS data to be 14 500 t of contained lithium, a slight decrease since 2002. However, information on USA and Russian production is withheld by the USGS for commercial reasons. Chile with 41% remained the world's largest producer, followed by Australia (24%), China (17%) and Argentina (7%).

Industry Developments

There were no significant new developments in Australia's lithium industry in 2003.

Magnesite

Magnesite (magnesium carbonate) is marketed in three main forms: (1) crude magnesite, primarily for use in chemicals and agriculture; (2) dead-burned magnesia, a durable refractory for use in cement, glass, steel and in metallurgical industries; and (3) caustic calcined magnesia, for use in making oxychloride and oxysulphate cements for flooring and wallboards, mouldings and acoustic tiles, and various environmental and chemical applications.

Resources

EDR of magnesite decreased by about 6% to 344 Mt in 2003 compared with 363 Mt in 2002. Production from the Kunwarara mine (Qld) accounted for the change. In South Australia, the largest holding of EDR, a global resource of 579 Mt of magnesite has been identified in the Willouran Ranges, northwest of Leigh Creek. About 235 Mt of this resource in the Mount Hutton and Witchelina deposits is classified as EDR, unchanged from 2002.

Queensland has the second largest inventory of magnesite EDR. The bulk of this occurs at Kunwarara (70 km northwest of Rockhampton), where Australian Magnesium Corporation Ltd has an inferred global resource of 1200 Mt of magnesite-bearing material. Within this global resource, which has an inferred resource of 500 Mt of magnesite, the company has identified several high-grade magnesite zones which are classified as EDR. The Kunwarara deposit contains substantial accumulations of very high-density 'bone-type' magnesite characterised by nodular and cryptocrystalline structure and low iron-content.

The third largest inventory of EDR is in Tasmania where the Arthur River deposit has an indicated resource of 29 Mt of magnesite, unchanged from 2002. Magnesite in the deposit typically 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.

Minor EDR occurs in the Winchester deposit (near Batchelor, NT), at Thuddungra (80 km northwest of Young, NSW), and at Bandalup (20 km east of Ravensthorpe, WA).

Subeconomic demonstrated resources of 57 Mt of magnesite remained unchanged from 2002. All of these resources occur in Queensland and Tasmania.

Inferred resources decreased by about 6% in 2003 to 931 Mt with Queensland accounting for 50% of these resources followed by South Australia (31%) and Tasmania (16%).

Accessible EDR

Currently, all magnesite EDR is accessible for mining.

JORC Reserves

About 11% of AEDR comprise JORC Code reserves. The remaining represents resources assessed by Geoscience Australia from the measured and indicated categories of industry reported mineral resources, as defined under the Code and other classification systems used by companies not listed on the Australian Stock Exchange. At Australia's 2003 rate of production, magnesite resources in the JORC Code reserves categories are adequate for 80 years.

Exploration

Data relating to exploration expenditure for magnesite are not published by ABS on either a state or national basis.

Production

In 2003, Australian Magnesium Corporation Ltd mined 3.02 Mt (2.14 Mt in 2002) of crude magnesite ore at Kunwarara, which was beneficiated to produce 470 038 t of magnesite (483 002 t in 2002). This in turn produced 108 190 t of dead-burned magnesia (102 785 t in 2002), 56 143 t of calcined magnesia (58 688 t in 2002), and 25 064 t of electrofused magnesia (19 582 t in 2002). The only other recorded production of magnesite in 2003 was about 2 600 t in South Australia.

World Ranking

According to Geoscience Australia and USGS data, Australia has about 5% of the world's EDR of magnesite. Russia, North Korea and China, together, account for nearly 70% of the world's EDR of magnesite. The Kunwarara deposit is the world's largest known resource of cryptocrystalline, nodular magnesite, a high quality ore.

Australia accounted for 4% of the world's production in 2003. USGS data show that China (33%) and Turkey (17%) were the world's largest producers, followed by North Korea and Russia (both 9%), and Austria (6%).

Industry Developments

Australia's potential capability to produce magnesium metal changed markedly in 2003. In June, **Australian Magnesium Corporation Ltd** (AMC) mothballed construction of its \$1.7 billion **Stanwell** magnesium plant near Rockhampton (Qld) due to a capital cost overrun and failure to attract a new corporate partner into the project.

AMC has reached an agreement with both the Australian and Queensland governments as stakeholders to exit their positions as secured creditors, extinguishing all their debts, and walk away with \$46.4 million in cash, as well as the land on which the plant was to be built. The plant site will be reserved as a site for a magnesium plant for five years. AMC will continue the QMAG magnesia operation, which is a stand-alone business.

Magnesium International Ltd (MIL) concluded an agreement with CSIRO to produce magnesium sheet metal using twin-roll casting technology developed by CSIRO. MIL announced a new strategy for the SAMAG project that would increase the planned production rate by 18% to 84 000 tpa. The aim is to construct the proposed smelter in two modules, with the first having a capacity of 41 000 tpa. When the first module is commissioned and production optimised, construction would commence on

the second module. This strategy would reduce financial risks and provide operating revenue to reduce capital requirement for the second module.

The South Australian Government reaffirmed its commitment to MIL's **SAMAG Magnesium Project** at **Port Pirie** (SA) following a comprehensive review of the project, which included engineering, technology, capital and operating cost estimates, market analysis and the proposed financial arrangements. The government is to provide \$25 million in infrastructure support to the project.

By the end of the year, MIL was having discussions with a number of companies regarding the development of a power station near the site of the proposed smelter at Port Pirie with the final decision to be made early next year.

MIL was investigating a new source of magnesite near **Collaby**, in the southern Flinders Range, 15 km from Port Pirie, as an alternative to the original supply from mines 250 km away near Leigh Creek.

In 2003, **Latrobe Magnesium Ltd** (formerly Rambora Technologies Ltd) was negotiating with Alcan to use their magnesium extraction technology for its proposed brown coal fly ash tailings-to-magnesium project in the **La Trobe Valley**, Victoria.

In May, the company signed a contract with Yallourn Energy Pty Ltd for the supply of about 320 ktpa of ash for the project. This contract together with arrangements already in place with Hazelwood Power has secured for the company sufficient feedstock to produce 75 ktpa of magnesium metal for a period of at least 20 years.

Latrobe Magnesium Ltd is proposing to produce magnesium metal from fly ash produced by the La Trobe Valley power stations. The company commenced a bankable feasibility study in June 2003 that includes a plan to process 1.2 Mtpa of fly ash with a magnesium content of up to 12% to produce about 100 000 tpa of magnesium metal.

Manganese Ore

Manganese is a grey white coloured metal, resembling iron, but harder and very brittle. In nature, manganese occurs most commonly as the minerals pyrolusite (manganese dioxide MnO_2) and rhodochrosite (manganese carbonate $MnCO_3$). Manganese is the twelfth most abundant element in the Earth's crust and the fourth most used metal after iron, aluminium and copper. The main uses for manganese are in the production of stainless and special steels and silico- and ferromanganese alloys. Over 90% of the world's production of manganese is applied in the desulphurisation and strengthening of steel. Manganese is also used in the manufacture of dry batteries, as a colorant, and as an ingredient in plant fertilisers and animal feed.

In Australia there are two operating manganese mines – Groote Eylandt (NT) and Woodie Woodie (WA). Manganese ore processing plants are located at Bell Bay (Tas) and Newcastle (NSW).

Resources

In 2003 Australia's EDR of manganese ore decreased by 2.3% to 124 Mt mainly due to production. Both paramarginal demonstrated resources (23.1 Mt) and submarginal demonstrated resources (167 Mt) remained unchanged. Inferred resources also remained unchanged at 197 Mt.

Accessible EDR

All manganese ore EDR (124 Mt) is accessible. The resource life is about 25 years at current rates of production of beneficiated manganese ore.

JORC Reserves

Manganese ore JORC reserves are 89 Mt (72% of accessible EDR). The resource life based on JORC reserves and at the current rate of production of beneficiated manganese ore is about 17 years.

Exploration

Data relating to exploration expenditure for manganese are not published by ABS on either a state or national basis.

Approximately \$2.6 million was spent on exploration at Woodie Woodie during 2003. Consolidated Minerals Pty Ltd exploration program in 2003 included SAM (sub-audio magnetics), geological mapping, gravity surveys, RC and RB drilling and aerial photography. The areas explored were the Woodie Woodie tenements, Ilgarari, Tarra Tarra and Sunday Hill all in Western Australia and Pernatty in South Australia.

In April 2003, GEMCO announced plans to spend \$2.3 million exploring the Bootu Creek project (NT) for a 25% stake. This will complete a feasibility study on the project which has the potential to produce 300 ktpa for 20 years.

Production

In 2003, production of manganese ore at Groote Eylandt was 1.94 Mt and at Woodie Woodie 0.61 Mt. ABARE reported that Australia produced 2.55 Mt of manganese ore with a manganese content of 1.2 Mt. Exports for 2003 totalled 2.31 Mt valued at \$336 million.

World Ranking

Australia has 13% of the world's EDR of manganese ore and is ranked third behind Ukraine (42%) and China (21%). South Africa has substantial resources; however South African EDR is based on reported company estimates of proven and probable reserves which ranks them fourth after Australia. In terms of contained manganese, Australia has 17% of the world EDR and is ranked second behind Ukraine (41%).

Australia produces 12% of the world's manganese ore and is ranked third behind China (22%) and South Africa (17%).

Loading manganese ore at the Woodie Woodie mine, Western Australia.
(Consolidated Minerals Ltd)



Industry Developments

GEMCO has been mining manganese on **Groote Eylandt** since 1964. The company uses open-pit strip mining methods at the Groote Eylandt deposit. Mined ore is beneficiated then transported to Milner Bay for stockpiling before being loaded onto ships.

The current **Woodie Woodie** project, which commenced in May 1999, utilises conventional open-pit mining methods from multiple pits to achieve consistent product grades. Mined ore is fed into a beneficiating plant that produces a lump and fine product which is trucked 400 km by 90 t road trains to Port Hedland for overseas shipment. During 2003, **Consolidated Minerals** developed an optimised long term mining plan for the Woodie Woodie operation that ensures a 10 year mine life.

HiTec Energy Ltd is proposing to produce electrolytic manganese dioxide (EMD) in the **Kalgoorlie region**. In 2003 HiTec purchased the solvent extraction plant and electrowinning cell house at the Cawse nickel operation for \$3.5 million. This purchase reduced the initial capital expenditure, the operating costs and the market risk profile of the project compared to operating a plant at either Geraldton or Port Hedland. HiTec is now proposing to create a Stage 1, \$52 million, 12 500 tpa project utilising Woodie Woodie tailings and waste manganese from the Kalgoorlie region. Completion of the feasibility study is expected in early 2004. In November 2003, HiTec was granted a Commonwealth Government R&D Start Grant of \$357 000 to pursue further R&D work directed at commercialising HiTec's solvent extraction process.

Mineral Sands

The principal components of mineral sands are the titanium minerals, rutile and ilmenite, and zircon. Rutile and ilmenite are mainly used 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 used as an opacifier for glazes on ceramic tiles, in refractories and for foundry industry.

Resources

The EDR of **ilmenite** increased 5.3% to 208.8 Mt in 2003, from 198.2 Mt in 2002.

Australia's largest holding of ilmenite EDR (63%) is in Western Australia. With new resources identified in the Southern Swan Coastal Plain, south of Perth, total resources in WA increased by 4%, despite decreases due to mine production in the Northern Swan Coastal Plain and Scott Coastal Plain areas.

In Queensland, the second largest holding (25%), ilmenite resources decreased slightly due to mine production.

Successful exploration in the Murray Basin by Iluka Resources Ltd, BeMax Resources NL and Southern Titanium NL resulted in ilmenite resources increasing in Victoria by 21%, in New South Wales by 27%, and in South Australia by 32%. As a consequence, Victoria has 6% of the total ilmenite EDR and New South Wales about 5%.

The EDR of **rutile** (which includes leucoxene in Western Australia) declined by 9.4% from 23.5 Mt in 2002 to 21.3 Mt in 2003. The bulk of the decrease was in WA, where the combined rutile and leucoxene resources decreased by 32%. The decrease occurred on both the Northern Swan and Southern Swan Coastal Plains. In Queensland, rutile resources fell slightly due to mining loss. Despite these declines, Queensland and Western Australia together hold 64% of Australia's EDR of rutile.

Rutile resources in the Murray Basin of Victoria and New South Wales increased by 19% and 9%, respectively and declined by 35% in South Australia.

In the South Australian and New South Wales portion of the Murray Basin, 2.026 Mt of **leucoxene** resources were classified as EDR in 2003. The leucoxene resources of the Victorian part of the Murray Basin were included with the rutile resources.

The EDR of **zircon** increased by 9.4% from 29.5 Mt in 2002 to 32.2 Mt in 2003, the result of successful exploration especially in WA, where zircon resources increased along the Northern Swan Coastal Plain and the Southern Swan Coastal Plain by 12% and 18%, respectively. Increases in EDR of zircon occurred in the Murray Basin particularly in Victoria and New South Wales (32% and 17%, respectively). Western Australia and Queensland together have 80% of Australia's EDR of zircon (down from 81% in 2002).

Australia's subeconomic demonstrated resources of ilmenite, rutile and zircon remained unchanged in 2003 at 51 Mt, 12 Mt and 19 Mt, respectively. Over 97% of these resources are recorded in the paramarginal category, and are associated with the WIM deposits in the Murray Basin in Victoria. The WIM deposits also contain 14.38 Mt of leucoxene.

Inferred resources of **ilmenite** fell marginally to 106.8 Mt from 107 Mt in 2002. There was an increase of 4% in Victoria ilmenite resources due to successful ongoing exploration in the Murray Basin. In Western Australia, an increase of 16% in ilmenite resources was the outcome of increased exploration on the Northern Swan Coastal Plain, north of Perth, and the Scott Coastal Plain. These increases in resources were offset by the decrease in New South Wales (down by 24%) brought about by the upgrading of that State's ilmenite resources to EDR. Victoria is the main holder of the inferred ilmenite resources with 39% of the Australian total followed by New South Wales and Western Australia (each with about 22%). Inferred ilmenite resources in Queensland, with 11% of Australia's total, remained essentially unchanged in 2003.

Inferred resources of **rutile** fell by 4% with the decreases in New South Wales and South Australia offsetting increases in Victoria and Western Australia. Victoria is the main holder of inferred rutile resources with 55% of the Australian total followed by New South Wales (29%) and South Australia (8%).

Inferred resources of **zircon** declined by 5% with the decreases in New South Wales and South Australia offsetting the increases in Victoria and Western Australia. Victoria is the main holder of zircon inferred resources with 58% of the Australian total, followed by New South Wales (20%), Western Australia (9%) and South Australia (7%).

Accessible EDR

Some 17%, 27% and 26% (compared with 18%, 24% and 28% in 2002) of Australia's total EDR of ilmenite, rutile and zircon, respectively, are inaccessible for mining. These resources are in areas that are quarantined from mining and now largely incorporated into national parks. These areas include Moreton Island, Bribie Island, Fraser Island, 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 NSW.

JORC Reserves

Approximately 23% of ilmenite, 21% rutile and 21% zircon AEDR comprise JORC Code reserve. The remaining represents resources assessed by Geoscience Australia from the measured and indicated categories of industry reported mineral resources, as defined under the Code and other classification systems used by companies not listed on the Australian Stock Exchange.

Duration of Resources

At Australia's 2003 rate of production, AEDR of ilmenite, rutile and zircon are sufficient for an average of 85, 90 and 50 years respectively. However, resources in the JORC Code reserves categories are adequate for only 14 years for ilmenite, 21 years for rutile, and 12 years for zircon.

Exploration

According to quarterly ABS figures, expenditure on exploration for mineral sands in 2003 was estimated at \$26.3 million (compared with \$30.7 million in 2002). This represents a decrease of about 14% over the previous year. Comprehensive State-by-State data are not published by ABS, however it is likely that the expenditure was shared between the North and South Swan Coastal Plains of Western Australia and the Murray Basin, where EDR of mineral sands have increased.

Production

In 2003, Australia produced 2.01 Mt of ilmenite, 173 000 t of rutile, 58 000 t of leucoxene and 462 000 t of zircon (compared with 1.92 Mt of ilmenite, 218 000 t of rutile, 39 000 t of leucoxene and 408 000 t of zircon in 2002). The bulk of Australia's rutile and zircon production is exported compared to about 43% for ilmenite. The remaining ilmenite is upgraded to synthetic rutile containing about 92-94% TiO₂. In 2003, Australia produced 666 000 t of synthetic rutile (compared with 628 000 t in 2002).

World Ranking

According to Geoscience Australia and USGS data, Australia has the world's largest EDR of ilmenite, rutile and zircon with 33%, 43%, and 42%, respectively. Other major country rankings include South Africa (15%) and Norway (10%) for ilmenite; South Africa (16%) and India (13%) for rutile; and South Africa (30%) and Ukraine (8%) for zircon.

In 2003, world production of ilmenite decreased by 3% to 8.11 Mt, rutile increased by 7.7 % to 420 kt, and zircon increased by 7.2% to 890 kt. Australia's production accounts for about 25%, 41% and 52% each of world production of ilmenite, rutile and zircon, respectively. Not only is Australia the world's leading producer of all three minerals including synthetic rutile, it is also the largest exporter. South Africa (from dune sands) and Canada (from hard rock) mine similar quantities of ilmenite to Australia, however both countries upgrade the ilmenite to titanium slag, which contains between 75 and 94% TiO₂, prior to export. Other major world producers are for rutile South Africa (27%) and Ukraine (16%), for zircon South Africa (31%) and the USA (11%).

Industry Developments

Companies that produced heavy mineral sands during 2003 were **Iluka Resources Ltd**, **Cable Sands (WA) Pty Ltd**, **TiWest** joint venture, and **Doral Mineral Sands Pty Ltd** all in Western Australia, **Consolidated Rutile Ltd** (Queensland) and **Murray Basin Titanium Pty Ltd** (Victoria). **Mineral Deposits Ltd** (NSW) ceased mining in mid-2003. Potential greenfields mineral sands project in Australia include **BeMax Resources Ltd's Poocarrrie** mineral sands project (NSW), **Iluka's Douglas** project, **Southern Titanium Ltd's Mindarie** project (SA) and the **Coburn** project of **Gunson Resources Ltd** (WA).

Iluka Resources Ltd produced 69 922 t of rutile, 0.471 Mt of synthetic rutile, 1.033 Mt of ilmenite, 0.311 Mt of zircon, and 13 702 t of Hyti91 in 2003 from its six open-pit mining operations at **Eneabba** and **Capel**, and two synthetic rutile plants and a zircon finishing plant at Geraldton. The company is the second biggest titanium dioxide feedstock producer in the world behind Rio Tinto and the largest zircon producer. Production increased during 2003 due to improved mineral processing rates and increased mining tonnages. However, the rutile production was lower in 2003 than 2002, primarily as a result of declining rutile grades from the company's Eneabba operations. Current proven and probable reserves for the mid-west operations north of Perth are 222 Mt of ore grading 6.2% heavy minerals (HM), for a total 13.75 Mt of heavy mineral concentrates. The southwest operations have current proven and probable reserves of 108 Mt of ore, grading 9.3% HM, for a total 10.9 Mt of heavy mineral concentrates.

A feasibility study by **Iluka Resources Ltd** into the refurbishment of a synthetic rutile kiln at **Capel** to increase the capacity to 50 000 tpa synthetic rutile returned negative results due to the age of the equipment and the cost of modifications. The company is assessing other options for expansion, including modifications to increase output from existing kilns at Geraldton, a new kiln based on existing technology, or utilising a NewGenSR pilot plant.

The **TiWest joint venture** (Kerr McGee Corporation 50%, Ticor Ltd 50%) is the world's largest integrated titanium dioxide project, incorporating a dredging and dry-mining heavy mineral sands operation at **Cooljarloo** (170 km north of Perth), dry separation and synthetic rutile plants at **Chandala** (60 km north of Perth) and titanium dioxide pigment plant in **Kwinana** (30 km south of Perth). In 2003, about 23 Mt of ore grading 3.2% heavy minerals was mined producing 0.687 Mt of heavy mineral concentrates which were processed through the Chandala plant. Production in the

latter part of the year came from the Cooljarloo South mine and from the retreatment of remnant stockpiles. In 2003, the company produced 0.433 Mt of ilmenite, 0.08 Mt of zircon, 0.34 Mt of rutile, 0.31 Mt of leucoxene, 0.194 Mt of synthetic rutile, and 94 700 t of TiO₂ pigment. Current proven and probable reserves for the Cooljarloo operations are 170.7 Mt of ore grading 3.1% HM, for a total 5.22 Mt of heavy minerals.

Ticor purchased junior company **Magnetic Minerals Ltd** for \$26 million in early 2003, following an off-market takeover bid launched in late 2002. Magnetic had defined 9 Mt of heavy minerals at its **Dongara** project (26 km southeast of Dongara), which was contiguous with the Cooljarloo operations. Magnetic reported during mid-2002, that the Dongara project could support a mining operation of 350 000 tpa of heavy mineral concentrate producing 200 000 tpa ilmenite, 30 000 tpa rutile, and 30 000 tpa zircon over a planned 10-year mine life. Metallurgical testwork confirmed that the resources were of sufficient quality for marketing of products or capable (with certain plant modifications) of being treated through Tiwest's synthetic rutile plant.

Falcon Minerals Ltd (formerly **Yardarino Mining Ltd**) sold its Cooljarloo mineral sands project (50 km northeast of Lancelin) to the Tiwest joint venture for \$650 000 in April 2003. The Cooljarloo project has a total resource of 10.9 Mt grading 1.5% HM.

Following the unsuccessful attempt in late 2002 to sell its properties, **Nissho Iwai**, owners of Cable Sands (WA) Pty Ltd, continued operations at **Jangardup** (43 km east of Augusta), **Sandalwood** (20 km northeast of Bunbury) and **Yarloop** (13 km north of Harvey). The company is awaiting various statutory approvals to develop projects at **Tutunup** (14 km south of Capel), Ludlow (7 km southwest of Capel) and **Gwindinup** (16 km south of Bunbury). The Tutunup project received environmental approvals from the Environment Protection Authority (EPA) in late 2002. The mining will be undertaken solely on agricultural land, and will not affect the Tutunup State Forest. At Ludlow, EPA approval for a four-year mining operation was given in late 2003. The Gwindinup project, which has been the subject of a feasibility study, is expected to commence within 12 months of statutory approvals being granted. Plans by Cable Sands (WA) Pty Ltd to develop the Jangardup South deposit, 45km east of Augusta (WA), were boosted when a Native Title agreement was signed following two years of negotiations with the Boorjarah people.

Production of rutile and zircon from **Consolidated Rutile Ltd's** (CRL) dry mill in 2003 was 19% lower compared with 2002 due to difficult mining conditions at the **Yarraman** mine as well as a three month shutdown of the Yarraman dredge for repairs when the cutter head became trapped in the mine face at the time of a face fall. To offset this production loss, the company commenced supplementary dry mining in the first week of September within the existing Yarraman dredge mine path, feeding ore via a dry mining slurry unit to the Yarraman floating concentrator. Supplementary dry mining was also commissioned at the Ibis mine during October 2003.

In October 2003, CRL announced the signing of a Memorandum of Understanding (MOU) with **Austpac Resources NL** concerning the supply of ilmenite directly from CRL's mining operations to Austpac's proposed synthetic rutile (SR) plant. Under the terms of the MOU, CRL will supply 70 000 t of ilmenite per year to Austpac, subject to the following:

- completion of a successful independent bankable feasibility study for the proposed SR plant and Austpac obtaining finance,
- resolution of ilmenite pricing in accordance with the terms of the MOU, and
- construction and successful commissioning by Austpac of a 30 000 tpa SR plant based on their proprietary SR technology.

CRL approved plans in late June 2003 to upgrade the Ibis dredge plant in early 2004 and to dredge directly from the Ibis mine to the Enterprise deposit once the upgrade was completed. The upgrade includes the construction and installation of a thickener to manage higher clay levels (5.5% at the Enterprise deposit compared with 3% at the Ibis deposit) to maintain current production levels. The company expects to complete mining operations at the Ibis deposit and to complete the plant modifications, upgrades and commissioning activities by the end of second quarter 2004.

The company expects mining at the Yarraman deposit to cease in 2012 with a subsequent relocation of the Yarraman plant and equipment to the northern sector of the Enterprise orebody for the remaining mine life of that deposit.

Mineral Deposits Ltd's mining operations at **Viney Creek** (NSW) ceased in January 2003 and at Fullerton (NSW) during July 2003, both due to declining ore grades. The company commenced dismantling the Fullerton dredge and floating concentrator in early 2004 in preparation for shipping to Senegal, West Africa. The dredge pond at Fullerton was restored to its natural sand dune condition and the mining lease covering the deposit was cancelled.

Murray Basin Titanium Pty Ltd, a 50:50 joint venture between Sons of Gwalia and RZM Pty Ltd, operates the **Wemen** mine near Mildura (Vic), which in the year ended June 2003 produced 28 239 t of rutile, 10 841 t of zircon and 50 984 t of ilmenite. Following a review of the operation, the company demonstrated that the low shipping cost to Bunbury (WA) via Portland combined with the low unit processing cost at the higher capacity Cable Sands' Bunbury mineral separation plant (MSP) would significantly enhance the project economics of the Wemen operation in the short term. Consequently, the company placed the **Mildura** MSP on care-and-maintenance pending the outcome of an ongoing feasibility study for Phase 2 of the Murray Basin Development Programme, and commenced transporting the mineral sands concentrates to Cable Sands' MSP in Bunbury for treatment.

Gunson Resources Ltd continued work on the **Coburn Sands** (250 km north of Geraldton) pre-feasibility study. The Amy Zone mineralisation, discovered in 2000, consists of an upper dunal horizon grading between 0.87% and 2% HM, and a lower, marine horizon with a high-grade core zone of over 2% HM. The company was evaluating two mining options, the first a conventional dredge and concentrator, the second a dry mining operation. The dry mining of the deposit had the lower initial capital costs. Under this proposal, mining would be by front-end loader, with ore dumped into hoppers and slurried to a skid mounted heavy mineral concentrator located on the pit floor. The concentrates would then be trucked to a dry mineral separation plant in Geraldton. The current reported inferred resource at Amy is 9.315 Mt of heavy minerals, in 690 Mt of sand averaging 1.35% HM, and contain on average 23% zircon, 6% rutile and 60% ilmenite-leucoxene.

During 2003, **Olympia Resources NL** continued mineral sands exploration in southwest Western Australia, at its **Pinjarra** (formerly Waroona) project 35 km northeast of Harvey, WA, where the company is in joint venture with Doral Mineral Industries Ltd. The project has defined inferred resources at the Coolup/Coolup East (455 000 t of ore grading 9.8% HM for 45 000 t of heavy minerals), The Loop (11.5 Mt of ore grading 7.2% HM for 820 000 t heavy minerals), North Dandalup (1.1 Mt of ore grading 4.1% HM for 45 000 t of heavy minerals), and Keysbrook (32 Mt of ore grading 3.1% HM for 990 000 t of heavy minerals) deposits. Olympia also acquired the Ambergate project (8 km south of Busselton) from Quantum Resources Ltd who previously had outlined an inferred resource of 0.611 Mt of heavy minerals.

Southern Titanium NL has expanded the scope of its definitive feasibility study on the **Mindarie** project, 120 km north of Adelaide (SA) to incorporate new strandlines. The Mindarie deposits contain one of the highest ratios of premium-grade zircon to titanium minerals in the world. The project resource base as at September 2003 stood at 327.4 Mt for a combined 8.3 Mt of heavy minerals (at a 1% cut-off grade). The resource estimates comprise: measured 14.1 Mt of ore grading 3.45% HM, indicated 141.9 Mt of ore grading 3.18% HM, and inferred 171.4 Mt of ore grading 1.95% HM. The company plans to mine 69 Mt of ore and with annual production rates of 35 000 t premium zircon, 8 200 t rutile, 7200 t leucoxene, and 72 000 t ilmenite over a mine life of 12.5 years.

The company has signed an off-take agreement with **DCM DECOMetal International Trading GmbH** (DCM) for the sale and purchase of 100% of planned output. DCM will also have responsibility for all logistics including transportation to ports, warehousing, and ship-loading of the mineral products, conveyance, as well as marketing.

BeMax Resources NL (BeMax) has completed its definitive feasibility study and received all approvals from the NSW Government for the development of the **Ginkgo** deposit, near Pooncarie. The operation is expected to produce 450 000 tpa of HM concentrates over a 25-year mine life with mineral separation taking place at Broken Hill.

In October 2003, BeMax signed a Heads of Agreement with **Nissho Iwai Corporation** and **Sons of Gwalia Ltd** to merge their Australian mineral sands assets to form a new Australian titanium dioxide producer. BeMaX will become the public entity of the unit, and will become Australia's third-largest producer of TiO₂ feedstock. The amalgamation includes the mineral sands operations in Western Australia, and consolidation of the Pooncarie mineral sands project within the Murray Basin with the Murray Basin Titanium Joint Venture that includes the Wemen mining operation. The agreement will result in Nissho Iwai holding 20.3% of BeMax and Sons of Gwalia holding 15.36%. The other major shareholder will be the **National Titanium Dioxide Company** (Cristal) of Saudi Arabia, which will own 26.99%. Formal agreements to effect this merger were executed on 2 February 2004. Completion of the merger was announced on 4 May 2004.

Nickel

More than 80% of the world's nickel production is used in alloys. When alloyed with other elements, nickel imparts toughness, strength, resistance to corrosion, and various other electrical, magnetic and heat resistant properties. About 65% of world nickel output is consumed in the manufacture of stainless steel. Stainless steels are widely used in the chemical industry, consumer products (eg sinks, cooking utensils, cutlery and white-goods), motor vehicles and the construction industry.

Resources

EDR increased by 2.6% in 2003 from 22.2 Mt to a record 22.8 Mt. All of the increase in EDR occurred in Western Australia, and mainly reflected industry reassessments of resources at existing deposits. Of this amount, about 26% of EDR was in sulphide ores, and the remaining EDR was associated with laterites.

Western Australia remains the largest holder of nickel resources with 90% of total Australian EDR (unchanged from 2002). EDR at the operating sulphide mines of WMC Resources Ltd's Kambalda and Leinster, MPI Mines Ltd's Black Swan, Jubilee Mines NL's Cosmos, Mincor Resources NL's Miitel and Wannaway, and Tectonic Resources NL's RAV 8 decreased reflecting depletion of resources through production. EDR at Minara Resources NL's Murrin Murrin lateritic nickel mine declined due to a combination of production and reassessment by the company of the laterite resources at that deposit.

Company reassessment at MPI Mines Ltd's Honeymoon Well, together with successful ongoing exploration in the vicinity of former mines such as Beta, Blair, Carnilya Hill, and at Sherlock Bay deposit and the Forrestania Nickel project offset resources loss through mining, resulting in an overall increase in EDR.

EDR in New South Wales, the second largest holder of EDR with 7%, in Queensland (2.6%) and in Tasmania (0.2%) remained unchanged from 2002. Nickel resources in both New South Wales and Queensland are associated with laterite deposits whereas those in Tasmania are hosted in sulphides at the North Averbury deposit, 7 km west of Zeehan.

Subeconomic demonstrated resources, which accounted for about 9% of total identified resources, decreased by 0.5 Mt during the review period. The paramarginal resources (majority of which are in WA), decreased by 0.4 Mt due to upgrading of resources to EDR. The submarginal resources decreased by 50 000 t in 2003. Western Australia has over 80% of the submarginal resources.

Inferred resources decreased by 1% to 16.4 Mt in 2003. The bulk of the decreases occurred in Western Australia. Although industry drilling has upgraded some resources to EDR, and led to new discoveries such as Windanya-Blue Patch prospect by Heron Resources Ltd, the resources of some undeveloped deposits, especially laterite deposits, has been reassessed downwards especially where

the company's initial resource estimates were considered very preliminary. However, despite the decrease in Western Australia, that State maintained its dominant share of Australia's inferred resources at 87% followed by Queensland with 10%.

The ratio of inferred resources to EDR decreased from 0.74:1 in 2002 to 0.72:1 in 2003.

Accessible EDR

Currently, all nickel EDR is accessible for mining. At Australia's 2003 rate of production, AEDR of nickel (including both sulphide and laterite) are sufficient for an average of 119 years.

JORC Reserves

About 30% of AEDR comprise JORC Code reserve. Of this amount, about 33% occur in nickel sulphide deposits and the remaining in nickeliferous laterite deposits. The remaining 69% of EDR represents resources assessed by Geoscience Australia from the measured and indicated categories of industry reported mineral resources, as defined under the Code and other classification systems used by companies not listed on the Australian Stock Exchange.

Total JORC Code reserves of nickel are adequate for an average of 35 years at current rates of production.

Exploration

Expenditure on nickel (including cobalt) exploration for 2003 totalled \$70.7 million, an increase of nearly \$16 million over 2002. The increase in expenditure was reflected in the rate of growth in EDR of nickel, which increased by about 0.6 kt in 2003. The forecast tightening of nickel supply over the next few years was also an incentive for companies to explore for nickel. About 78% of this exploration expenditure occurred in Western Australia.

Throughout 2003, nickel exploration continued to focus on the mafic-ultramafic Giles Complex in Western Australia and South Australia and the komatiite-hosted nickel sulphide deposits in the Yilgarn Craton, Western Australia. The East Kimberley region in northern Western Australia also attracted much interest. Some of the more encouraging exploration results in 2003 include the following:

- Independence Gold NL reported a high-grade nickel intersection from drilling on its **Victor South** project, near Kambalda, WA. The intersection reported was 15 m (true width) at 10.0% Ni including 10.6 m at 12.8% Ni.
- At **Radio Hill** in the Pilbara region of WA, Fox Resources Ltd reported that drilling aimed at testing extensions of mineralisation was successful. One hole intersected 18.0 m at 5.1% Ni equiv. (3.62% Ni, 3.06% Cu and 0.2% Co and 0.5 g/t Pd), and another 25.4 m at 4.4% Ni equiv. (3.25% Ni, 2.01% Cu, 0.16% Co and 2.15 g/t Pd).
- Titan Resources NL confirmed a nickel discovery at its **McEwen** prospect at Widgiemooltha, WA. A new high-grade zone was identified below the disseminated nickel mineralisation. Intersections that penetrated the zone returned 3 m at 4.64% Ni from 164 m, 2 m at 2.64% Ni from 158 m, and 4 m at 2.79% Ni from 180 m.
- Drilling at the **Cosmos** project by Jubilee Mines NL intersected new high-grade nickel sulphide mineralisation. Better intersections reported include 0.3 m at 13.1% Ni, 1.35 m at 3.9% Ni, and 0.55 m at 8.5% Ni. The company discovered a new zone of nickel sulphide, **Anomaly 3**, 4.5 km south of the Cosmos Nickel Mine. Drilling returned 68.1 m at 0.63% Ni from 175 m, 0.2 m at 13.1% Ni and 7.35% Cu from 243.1 m, and 4.05 m at 1.5% Ni from 243.3 m.
- Mincor Resources NL intersected both massive and matrix nickel sulphides in a drill hole located 300 m north of the **Redross** open cut in WA. The mineralisation occurs in two zones – an upper zone with 1.75 m at 1.46% Ni and a lower zone in which the main intersections were 3.46 m at 3.05% Ni and 0.83 m at 7.00% Ni.

- A measured resource of 9.0 Mt grading 0.53% Ni and 0.1% Co was reported by Central Kalgoorlie Gold Mines Ltd (now Sherlock Bay Nickel Corporation Ltd) for the **Sherlock Bay** nickel deposit near Karratha, WA. The deposit has a strike length of 590 m and is open at depth. Drilling yielded intersections including 13 m at 0.56% Ni, 11 m at 0.64% Ni, and 21 m at 0.57% Ni.
- View Resources Ltd announced a 130% increase in resources at the **Carnilya Hill** nickel mine near Kalgoorlie, WA. Total resources are 134 656 t at 3.56% Ni. The company reported high-grade intersections at the **Zone 29** project of 3 m at 5.4% Ni, 1.7 m at 6.7% Ni, and 1 m at 4.4% Ni.
- Massive sulphides were intersected by Australian Mines Ltd at the **Blair** mine at Kambalda, WA. Intersections included 1.6 m at 6.5% Ni. Significant nickel sulphides intersections were encountered at Area 57 including 3.60 m at 6.2% Ni and 2.65 m at 5.65% Ni.
- In a new nickel region, Westonia Mines Ltd reported nickel sulphides from drilling at its **Westonia** project, west of Southern Cross, WA. The mineralisation occurs in the Westonia Greenstone belt and two drill holes returned intersections of 16 m at 1.77% Ni from 44 m, and 10 m at 1.61% Ni from 30 m.
- Western Areas NL has reported an intersection of 6.6 m grading 7.9% Ni from 454.6 m downhole depth (including 3.7 m at 9.0% Ni) in the **Flying Fox** area of its Forrestania project, WA. Subsequently, it reported an aggregate intersection of 21.4 m at 7.79% Ni from 494 m downhole, from one drill hole and a second hole returned 6.6 m at 7.9% Ni. Further drilling intersected massive sulphides including 2.6 m at 5.2% Ni and 5.6 m at 3.6% Ni.
- Thundelarra Exploration Ltd announced that Sally Malay Mining Ltd had reported significant intersections at the **Copernicus** deposit in the East Kimberley region, WA including 17 m at 1.91% Ni and 1.45% Cu, 18 m at 1.52% Ni and 0.79% Cu, 23 m at 1.50% Ni and 0.72% Cu. The company also intersected 8 m at 1.75% Ni and 1.08% Cu in a drill hole south of the Copernicus deposit.
- Western Areas NL upgraded the nickel resource adjacent to the existing decline at **Cosmic Boy** to 189 000 t at 2.78% Ni. It also increased resources at **Digger Rocks** deposit by 20% to 54 900 t grading 3.72% Ni. An intersection of 3.7m at 5.5% Ni in the upper part of the **New Morning** deposit confirmed the continuity, thickness and high grade nature of the resource.
- At its Widgiemooltha North project 40 km south west of Kambalda, WA, Titan Resources NL intersected 9 m at 2.76% Ni from 88 m depth, including 2 m at 7.73% Ni from 95 m at its **Armstrong** deposit. This intersection is located up dip of the previously defined resources. At its **McEwen** deposit, the company has intersected 6 m of massive sulphides at 3.06% Ni from 166 m and at the **O'Grady** prospect 6 km south of Armstrong, intersections of 1 m at 4.82% Ni, and 24 m at 1.03% Ni were reported.
- Drilling by Mincor Resources NL at the south end of the **Mittel** orebody via a new underground drive intersected 6.88 m at 3.12% Ni (4.5m true width) and 4.88 m at 3.09% Ni (4.4 m true width). Both holes intersected the down-plunge extension of the high-grade N05 ore body. At the **North Mittel** deposit, resources were upgraded to an indicated resource of 306 800 t at 4.12% Ni (12 644 t contained Ni).
- Deep diamond drilling by **Sally Malay** Mining Ltd at Sally Malay in the East Kimberley region, WA intersected nickel sulphides over 7.4 m at 1.58% Ni, 0.74% Cu and 0.08% Co including a 4.4 m interval at 2.06% Ni, 0.98% Cu and 0.1% Co, approximately 650 m below surface. The drilling confirmed that mineralisation continues at depth below the main fault zone.
- Breakaway Resources Ltd intersected significant nickel sulphide mineralisation at its **5A** prospect, part of the Spargoville property, WA. Better results include 4.11 m at 6.29% Ni, 1.56 g/t Pd and 0.16 g/t Pt, 3.27 m at 5.33% Ni, 0.34 g/t Pd and 0.18 g/t Pt, and 2.97 m at 10.53% Ni, 0.26 g/t Pd and 0.31 g/t Pt. The mineralisation was intersected below the existing 5A open pit.
- At the **Wedgetail** prospect within the Honeymoon Well project, MPI Mines Ltd reported an intersection of 8.81 m at 6.52% Ni. At the Harrier prospect, also in the Honeymoon Well project, intersections of 0.35 m at 9.16% Ni, 0.28 m at 24.7% Ni and 3.95 m at 3.12% Ni were recorded.

Production

Australia's nickel production decreased in 2003 by 9% to 192 kt, all from Western Australia.

During 2003, total nickel-in-concentrates production by WMC Resources Ltd, the world's second largest nickel-in-concentrate producer, was 117 722 tonnes (representing 16% of the world nickel-in-concentrate production), 11% higher than for 2002 and the highest recorded by the company since 1998. This increase was due to record production from Mt Keith, increased output from Leinster and increased supply from the independent operators of divested Kambalda nickel mines. Nickel-in-concentrates production totalled 50 004 t at Mount Keith (43 192 t in 2002), and 41 806 t at Leinster (40 006 t in 2002). The Kambalda concentrator produced 25 912 t of nickel-in-concentrates, the bulk of which were purchased from third parties.

Nickel-in-matte production in 2003 from the Kalgoorlie smelter by WMC Resources Ltd totalled 99 152 t, 8% higher than for 2002.

World Ranking

Based on figures published by the USGS and modified to incorporate the Australian resources reported here, world EDR of nickel increased by 2.6% to 62.8 Mt in 2003 (61.2 Mt in 2002). Australia's share of world EDR was 36.3% in 2003 (unchanged from 2002), and it remained the largest holder of EDR followed by Russia (11%), Cuba (9%) and Canada (8%).

Russia was again the largest producer with 330 kt (24%), followed by Australia with 192 kt (13.7%) and Canada with 180 kt (13%). The fourth largest producer was Indonesia and New Caledonia each with an output of 120 kt (9%).

Industry Developments

Australia has several nickel sulphide mines currently in operation including **WMC Resources Ltd's Kambalda, Leinster** and **Mount Keith, MPI Mines Ltd's Black Swan, Tectonic Resources NL's RAV8, Jubilee Mines NL's Cosmos, Mincor Resources NL's Miitel** and **Wannaway, LionOre International Mining Ltd's Emily Ann**, and the **Independence Gold NL's Long-Victor**. Two laterite nickel mines were in operation: **OM Group's Cawse** and **Minara Resources NL's Murrin Murrin**. All these operating nickel mines are in Western Australia. Australia has one nickel smelter at Kalgoorlie, WA, and two refineries, one at **Yabulu**, Queensland and the other at **Kwinana**, WA.

In September 2003, boiler repairs interrupted production at the Kwinana refinery. As a result, refined metal production was 61 417 t, 6% lower than for 2002. The excess nickel matte feed was sold by the company into a strong spot market. The company commenced work to rectify bottle-necks in the refinery operations and to increase annual production capacity at Kwinana to 70 000 t. This work is due to be completed in 2004.

In February 2003, WMC Resources Ltd commenced a major extension of its Perseverance underground mine at Leinster. Over the next eight years, the company will extend mining activity 350 m deeper to 1100 m below the ground surface. A new materials-handling system to crush and hoist ore to the surface will be installed with most of the construction and development to be completed during the second half of 2005.

In August, WMC Resources Ltd entered into a \$1 billion agreement with China's largest producer, **Jinchuan Group** Ltd, to supply 90 000 t of nickel-in-matte. This agreement is in addition to a 30 000 t agreement signed in December, 2002. The company will export a total of 120 000 t of nickel-in-matte to Jinchuan between 2005 and 2010. When refined, this will represent more than 20% of the total domestic consumption of nickel metal in China in 2010.

Jubilee Mines NL commenced mining its **Cosmos Deep** ore body via the Ilias decline in the June quarter 2003 following the completion of open cut mining at the Cosmos orebody. Estimated future production, sourced from the underground development, is expected to be 150 ktpa of ore producing 50 000 t of nickel-in-concentrate containing 10 000 t of nickel and with a mine life of 3.5 years.

Western Areas NL is carrying out a bankable feasibility study (BFS) on its proposed \$70 million development of the Forrestania nickel project, and proposes to be in production by the end of 2005. The company was considering a 500 000 tpa mining and processing operation involving five mines and a concentrator, producing about 12 000 tpa of contained nickel for a mine life of six years. The BFS is expected to be completed in July 2004.

In April 2003, Sally Malay Mining Ltd commenced construction at its **Sally Malay** nickel project following the securing of a \$52 million loan in mid-March and obtaining all the necessary environmental approvals. The ore will be treated using conventional technology to produce a bulk Ni-Cu-Co concentrate, which will be exported through Wyndham to be treated at the Jinchuan Group Ltd smelter-refinery complex in China. Sally Malay Mining Ltd expects the mine to produce 344 500 t of bulk concentrate containing 45 600 t of nickel, 21 750 t of copper, and 2250 t of cobalt over a 5.5 year mine life. The first concentrate was shipped to Jinchuan, China in September 2004.

Reassessment of the **Radio Hill** mine by Fox Resources Ltd has shown that, with minimal new development, up to 751 000 t of ore at 0.8% Ni, 1.0% Cu and 0.05% Co from the disseminated sulphide zones could be mined economically using the existing decline, with an additional 107 000 t of ore at 0.9% Ni and 1.1% Cu mined by open pit from B2 orebody. These resources represent a mine life of about four years using the Radio Hill plant with its current production capacity of 220 000 tpa. Mining re-started at Radio Hill in June 2004 and the first shipment of nickel and copper concentrate was exported to China in late August 2004.

MPI Mines Ltd plans to commence open cut mining at the **Black Swan** deposit by the end of 2004. The company plans to do this in two phases. Phase one involves mining 450 000 tpa for 2500 t of nickel-in-concentrate and only requires a minimal upgrade to the existing milling and treatment facility. Commissioning of this phase utilising existing mill infrastructure is scheduled for the third quarter 2004. Phase two involves mining 1 Mt of ore per year, resulting in production of over 5000 t of nickel-in-concentrate. This phase will require increasing the power capacity, the provision of more water and upgrading the mill capacity.

MPI Mines Ltd's feasibility study for a proposed 250 000 tpa underground operation at **Wedgetail** (Honeymoon Well project) producing 10 000 tpa of nickel-in-concentrate is due for completion by the end of July 2004 with first production commencing in late 2005. The company indicated that an additional 20 000 tpa of contained nickel could be produced from the open cut mining and processing of around 4 Mtpa of disseminated sulphides grading 0.75% Ni. This disseminated sulphide material has low iron to magnesium ratio but relatively high arsenic content and, therefore is unsuitable as feedstock for the conventional smelting process. MPI Mines Ltd is considering a low-pressure sulphide leaching process using the Cawse laterite facility.

Independence Gold NL has increased reserves at its **Long** project to 688 000 t grading 4% Ni for 27 300 t of contained nickel metal. Resources now total 1.37 Mt at 6% Ni for 82 700 t of nickel metal. Another 27 000 t of contained nickel occurs in pillars but is not included in the resource estimates.

Australian Mines Ltd who acquired the **Blair** nickel mine from Blair Nickel Mine PL, a wholly-owned subsidiary of McMahons Holdings, commenced underground development work in December. Ore production is expected to start during the March quarter 2004 with the concentrates being toll-treated at WMC Resources Kalgoorlie smelter.

Titan Resources NL commenced pre-strip mining in early 2004 at its **Armstrong** deposit, which has reported resources of 465 000 t grading 2.12% Ni. The ore is to be toll-treated at WMC Resources nickel smelter. Underground operations will commence after the completion of the open pit.

Mincor Resources NL is to develop the **Redross** mine, 70 km south of Kambalda, WA, during 2004, at a cost of about \$11 million. The mine has a combined indicated and inferred resource of 0.345 Mt at 5.01% Ni.

Allegiance Mining NL has received environmental approval for development work at its Avebury nickel deposit, west of Zeehan in Tasmania. In March 2004, construction commenced on the access

road and 800 m long underground decline to enable bulk sampling and geotechnical assessment of the Viking and North **Avebury** deposits. An indicative feasibility study of the Avebury project demonstrated that an annual throughput of 400 ktpa for an initial period of two-to-three years producing about 5000 t annually of nickel-in-concentrate was commercially viable.

Australia's lateritic operations at **Cawse** and **Murrin Murrin** continued to experience mixed success throughout 2003. Minara Resources Ltd's (formerly Anaconda Nickel Ltd) Murrin Murrin operation produced 27 890 t of nickel in 2003 representing on average 62% of the plant capacity (45 ktpa of nickel). The operation was expected to achieve its production capacity by the end of 2004.

The laterite resources of the former **Bulong** project, owned by Preston Resources Ltd which went into receivership in 2002, were sold to Heron Resources Ltd. Negotiations were proceeding with a large international player to purchase the plant and equipment.

BHP Billiton has developed a proprietary atmospheric leach processes to be used on its **Ravensthorpe** laterite nickel project, WA. The Enhanced Pressure Acid Leaching (EPAL) hydrometallurgical process is a combination of pressure acid leach and atmospheric leach which produces a mixed nickel and cobalt hydroxide intermediate product (MHP). BHP Billiton plans to produce MHP containing up to 50 000 tpa of nickel and 1400 tpa of cobalt at Ravensthorpe that will be shipped through the Port of Esperance to Townsville, Queensland, for final refining at the QNI Yabulu refinery, with production commencing late 2007.

Niobium

Niobium is a by-product of tantalum mining at the Greenbushes operations in Western Australia. Niobium has traditionally been used in alloys by the steel and aerospace industries, however the use of niobium-titanium alloy wire in Magnetic Resonance Imaging has also created a niche for niobium in the medical industry.

Resources

Australia's EDR of niobium increased dramatically from 29 kt in 2002 to 194 kt in 2003. This was a result of increased resources at Greenbushes and at the Brockman rare earth deposit in Western Australia. Most of Australia's EDR of niobium resources occur in Western Australia with minor resources in New South Wales.

Subeconomic resources decreased to 115 kt Nb due to a reclassification of resources at the Greenbushes deposit.

Inferred resources also decreased, due to reclassification, to 1838 kt Nb.

Exploration

Exploration data for niobium are not available.

Production

The USGS report an estimated 250 t of production from Australia in 2003 (compared with 290 t in 2002). This production figure is an estimate of niobium in tantalum concentrates shipped from the Greenbushes operations. Separate concentrates of niobium are not produced at Greenbushes.

World Ranking

World EDR is estimated at 4604 kt of which Brazil has 4300 kt. Australia has the second largest EDR with 194 kt followed by Canada with 110 kt.

World production in 2003, based on USGS estimates, is 29 800 t Nb of which 26 000 t came from Brazil and 3400 t from Canada.

Industry Developments

Tantalum miner, **Tantalum Australia** reached an agreement to acquire two tantalum/niobium projects in the Gascoyne and Kimberley regions of Western Australia. The Gascoyne project is located 120 km NNE of Gascoyne Junction. The project tenements comprise two granted mining leases of 3 km² and three exploration licences.

The **Brockman** project, held by **Aztec Resources**, is situated in the East Kimberley, 18 km SE of Halls Creek. The project contains indicated and inferred resource of 50 Mt at 4400 ppm Nb, 270 ppm Ta and 1240 ppm Y. Tantalum Australia has the right to earn 60% of the Brockman project by spending \$1.5 million on exploration within three years.

Phosphate

Australia's commercial resources of phosphate are in Queensland (Phosphate Hill, 150 km 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 fertilisers for domestic and international use. The first di-ammonium phosphate (DAP) fertiliser utilising Phosphate Hill ore was produced in late 1999.

Christmas Island is a source of high 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) fertiliser.

DAP and MAP have different ratios of phosphorous and nitrogen, and have slightly different applications. Both products are generally produced as granules with a diameter of between 2–4 mm. DAP (20% P and 18% N) is used on broad-acre crops such as cereal, legume, fodder, horticultural and row crops, and dairy and newly-established pastures. MAP (22% P and 10% N) assists with early crop growth and enhances phosphorous uptake in broad-acre crops.

Resources

EDR of phosphate rock remained unchanged in 2003 compared to the previous year. All EDR is sedimentary phosphate rock (phosphorites), with an average grade of about 23–24% P₂O₅ at Phosphate Hill. There is no publicly available information on Christmas Island's phosphate resources. Geoscience Australia, however, has reasonably detailed knowledge of this deposit and known resources remaining within the existing mining lease on the island.

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 are distributed between Queensland and Northern Territory. Minor inferred resources also occur in Western Australia.

Exploration

Data relating to exploration for phosphate are not available.

Production

In 2003, WMC Resources' Queensland Fertiliser operations at Phosphate Hill produced 759 856 t DAP and 162 121 t MAP. Phosphate Resources' Christmas Island operations shipped 518 500 t of rock phosphate and 67 237 t of dust product in 2003.

World Ranking

Australia's EDR of phosphate rock comprises less than 1% of the world's total EDR of 18 Gt, which occurs principally as sedimentary marine phosphorites.

Industry Developments

During 2003, **WMC Resources** continued to increase rates of production for DAP and MAP, announcing a record total production of 921 977 t of fertilizer for the year. The company expects continuing production improvements during 2004 with planned output of 960 000 t. At this rate of production the life of the **Phosphate Hill** mine, based on current ore reserves, is expected to be at least 35 years.

Shale Oil

Oil shale is organic-rich shale that yields substantial quantities of oil by heating and distillation. One tonne of oil shale may contain over 200 litres of oil. The organic material in oil shale is kerogen, which can be a precursor to conventional oil reservoirs given appropriate conditions in the crust. Australian oil shale deposits of commercial interest are predominantly in a series of narrow and deep extensional-basins near Gladstone and Mackay in central Queensland. These are thick Tertiary lacustrine (lake-formed) deposits that are relatively easy to mine. They contrast with generally harder carbonate bearing oil shales (marls) found elsewhere in the world that are more difficult to mine and process.

Resources

Up until recently, all ten of the central Queensland oil shale deposits were held by Southern Pacific Petroleum (SPP), either solely or with joint venture partners. The last systematic review of the in situ mineralisation for these ten oil shale deposits was completed by SPP in 2000 to comply with the JORC Code. There was a minor revision made to these reserves and resource estimates by SPP in 2002 and these results are incorporated in this assessment.

Australia has 4.6 GL (29 million barrels) of shale oil economic demonstrated resources. This could increase significantly if the research and development demonstration-scale processing of shale oil at the Stuart deposit near Gladstone were to lead to a commercial plant. Paramarginal and submarginal demonstrated resources are 202.1 GL (1.3 billion barrels) and 3719 GL (23.4 billion barrels) respectively. The demonstration plant at Stuart has produced over 1.5 million barrels of oil. The shale tonnage processed was small in comparison to the overall resource, so there is no change in the reserves estimate at the reported level of precision.

Production

Oil production at the Stuart demonstration plant for the 2003 calendar year was up 94% to 100 ML (629 000 barrels). The oil production rate increased to over 3000 barrels per stream day in 2003.

The demonstration plant design ore grade is 172 litres per tonne at zero moisture (LT0M). The retorting has been tested with a range of input grades from 152 LT0M in July and August 2002 to 189 LT0M. Recovery rates have improved from 70% to a current recovery of 87%.

The oil products are Ultra Low Sulphur Naphtha (ULSN) 55–60% and Light Fuel Oil (LFO) 40–45%. Oil product sales in 2003 included 324 000 barrels of ULSN and 261 000 barrels of LFO. The ULSN, which can be used to make petrol, diesel and jet fuel, has a sulphur content of less than 1 ppm. To put this into perspective, petrol in Australia currently contains about 500 ppm sulphur. Regulatory guidelines are in place to reduce this to 150 ppm for petrol by 2005 and to 50 ppm for diesel by 2006.

World Ranking

The 2001 survey of energy resources by the World Energy Council reported that Jordan, Australia and Morocco have the largest deposits of 'proved oil shale in place'. The same survey also reported that production of oil from shale for 1999 was recorded in Brazil at 239 million litres and Estonia at 185 million litres.

Industry Developments

During 2004, ownership of SPP's oil shale assets passed to **Queensland Energy Resources Ltd** (QERL). QERL has announced that its **Stuart Stage 1** demonstration facility near Gladstone is expected to successfully complete its goals by the end of 2004. QERL plans to focus on conducting extensive research and design studies for the next phase of its Queensland oil shale operations based on the lessons learned from the demonstration plant.

QERL stated that the results to date from Stage 1 have demonstrated that large scale oil extraction from the Stuart deposit can be done. The company also added that over past years, the testing has shown that there are many potential alternatives and variations to the details of the Stage 1 design, which need to be fully explored if the value of these resources is to be maximised for all stakeholders. The facility will go onto care-and-maintenance in an operable condition to allow for any further testing if required while design efforts continue on the next phase of development.

Tantalum

After regaining lost ground in 2002, the demand for tantalum continued at a steady pace in 2003. Australia, through the operations of Sons of Gwalia Ltd, is the world's largest producer of tantalum in the form of tantalum concentrates. The company has world-class tantalum resources at the Greenbushes and Wodgina deposits (WA). Tantalum is used in the manufacture of tantalum capacitors which have applications in mobile phones, automotive electronics and computers.

Resources

EDR increased by 2% to 40 608 t in 2003 with an increase at Greenbushes offsetting a slight decrease at Wodgina and Bald Hill. Small resources in the EDR category occur elsewhere in Western Australia.

Subeconomic resources increased by 15% since 2002 due mainly to a reclassification of Wodgina where over 3000 t were added. Greenbushes also recorded an increase of over 1000 t.

An increase of almost 8000 t at Wodgina increased Australia's total inferred resources by 17% compared to the previous year's estimates.

Accessible EDR

All EDR of tantalum are accessible for mining.

JORC Reserves

Approximately 98% of tantalum AEDR comprises JORC Code reserves. The remaining represents resources assessed by Geoscience Australia as being economically recoverable from industry's measured and indicated categories of mineral resources, as defined under the Code.

Exploration

Data relating to exploration for tantalum are not available.

Production

In 2003, Sons of Gwalia produced 1 011 939 lbs (459 t) of Ta₂O₅ from the Greenbushes operation and a further 1 046 160 lbs (475 t) from its Wodgina mine. Haddington International Resources produced 181 623 lbs (83 t) of Ta₂O₅ at its Bald Hill deposit while Tantalum Australia's Dalgara operation remained on care-and-maintenance.

World Ranking

Based on world estimates published by the USGS and modified by Geoscience Australia to take account of recent discoveries, Australia has over 94% of the world's EDR of tantalum. Canada has the second largest resource base.

World production in 2003, based on USGS estimates modified to account for latest Australian data amounted to 1242 t Ta. Production was dominated by Australia, with 832 t Ta (1020 t Ta₂O₅) produced in 2003 (about 67% of world output). According to the USGS, other producers of tantalum metal were Brazil (which decreased its production to 200 t), Canada (58 t), Ethiopia (40 t) and Congo (30 t).

Industry Developments

Tantalum Australia acquired two tantalum/niobium projects in the Gascoyne and Kimberley regions of Western Australia. The Gascoyne project is located 120 km NNE of Gascoyne Junction. The Brockman project, held by Aztec Resources, is situated in the East Kimberley, 18 km SE of Halls Creek. The project contains an indicated and inferred resource of 50 Mt at 4400 ppm Nb, 270 ppm Ta and 1240 ppm Y.

Tantalum Australia had processed all previously mined ore at its **Dalgaranga** operation near Mount Magnet, Western Australia, by the end of 2002. Although the company had located more ore in proximal leases it was not processed because of the prevailing market conditions. The Dalgaranga plant was placed on care-and-maintenance in January 2003.

Tin

The main use for tin is in solders, which accounts for one third of world tin consumption. It is also used as a coating for steel in cans and containers, electrical conductors, and in metal alloys.

Following the collapse of the International Tin Council and the International Tin Agreement in 1985, tin prices (London Metal Exchange) fell sharply and remained at low levels for more than 15 years through to the end of 2002. During 2002, prices were at historic lows of around US\$3600/tonne tin, compared with more than US\$12 000/tonne prior to 1985. This prolonged period of low prices resulted in the closure of many tin mining operations in Queensland, New South Wales and Tasmania. Production at Renison Bell mine (Tasmania) was suspended in May 2003. During this period of low prices there was a decline in Australia's EDR of tin.

In 2003, world tin markets showed signs of recovery in response to reductions in tin stocks and decreases in mine production. Prices rose to US\$5000/tonne in by the end of 2003 before a rapid increase to more than US\$9000/tonne by mid-2004. In response to these price increases, several companies initiated proposals to re-open old mines, or to restart development of projects previously suspended because of low prices. In addition, some companies commenced exploration programs for tin.

Resources

Australia's EDR of tin are in three deposits: Renison Bell, Greenbushes (WA) and Ardllethan alluvials (NSW). At the end of 2003, Australia's total EDR was 146 kt tin, 40% higher than at the end of 2002. This was due to increases in ore reserves and mineral resources at Greenbushes and Ardllethan deposits.

Accessible EDR

All of Australia's EDR for tin are accessible for mining.

JORC Reserves

EDR is the sum of JORC Code reserves categories plus those measured and indicated resources which Geoscience Australia considers will be economic over the long term. In 2003, JORC Code reserves of 129 kt tin accounted for approximately 88% of AEDR.

Exploration

Marlborough Resources carried out exploration and drilling at several alluvial tin prospects in NSW, including Emmaville (50 km NE of Inverell) and Gibsonvale (100 km NE of Ardllethan) deposits.

Production

Mine production of tin in Australia has declined since the mid 1980s. At the start of 2003, Australia had three operating tin mines – Renison Bell underground mine (Murchison United NL), Ardlethon alluvial mine (Marlborough Resources NL), and Greenbushes open cut mine (Sons of Gwalia Ltd). Operations at Renison Bell were suspended in May, and by year's end, there were only two producing tin mines in Australia.

Production in 2003 was 3818 t tin (40% less than 2002). Total exports for 2003 were 2862 t tin valued at \$18 million.

World Ranking

Australia's EDR for tin is ranked number ten in the world. The world's major resources of EDR are in China, Malaysia, Indonesia, Peru and Bolivia.

Industry Developments

Mining and milling operations at **Renison Bell** mine were suspended following the company's failure to secure capital for development of a decline to access new ore reserves in the high grade Federal orebodies. Mining in the main stoping areas had been halted earlier in the year due to difficult ground conditions. Prior to suspension, this mine had been a major producer for almost 40 years and was one of the world's largest underground tin mining operations.

Production from the **Ardlethon** alluvial mining operations increased steadily throughout the year to reach a monthly rate of 136 t tin for December. The main factors contributing to this increase were:

- Commissioning of a second processing plant,
- Ore grades increased from 1.27 kg Sn/bank cubic metre (March quarter) to 2.15 kg Sn/bank cubic metre (December quarter),

The processing plants have combined capacity to treat 800 000 bank cubic meters of ore per year.

Greenbushes is the world's largest hard rock tantalum mine. Tin occurs in association with tantalum minerals and is recovered as a by-product during ore processing. The company operates a smelter at the site and tin is produced as refined ingot.

Bluestone Tin Ltd purchased the **Collingwood** project (North Queensland) from the previous owners in 2000 and completed a feasibility study in 2001. An Environmental Authority enabling the development of the project was issued to Bluestone in February 2003.

During the 1980s, an adit and underground development were completed at the Collingwood deposit, and a major drilling program was carried out from both surface and underground in order to outline the ore reserves and mineral resources. However, development of the project was deferred by the former owners in the late 1980s because of low market prices. Bluestone proposes to refurbish the adit and underground drives in late 2004, and production of tin is scheduled to commence in 2005. At Collingwood, cassiterite mineralisation occurs in a steeply dipping, sheeted vein system and in flat-lying greisen zones near the top of a granite intrusion.

Uranium

Uranium has two major peaceful uses: as the fuel in nuclear power reactors to generate electricity; and in the manufacture of radioisotopes for medical applications. Approximately 17% of the world's electricity is currently generated by the use of uranium in nuclear reactors. Some 441 nuclear power reactors with a total net capacity of over 364 gigawatts (electrical) are operating in 31 countries; a further 33 new reactors are under construction worldwide. A total of 16 countries generate more than 25% of their total electricity requirements from nuclear reactors. Australia has no significant national demand for uranium and all mine production is exported under nuclear safeguards agreements with importing countries.

Resources

Geoscience Australia 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). The estimates in each category are for recoverable resources of uranium after losses due to mining and milling have been deducted. 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 in table 3.

TABLE 3. Correlation of resource classification schemes for uranium.

National Scheme	NEA/IAEA Scheme
Economic Demonstrated Resources	Reasonably Assured Resources (RAR) recoverable at less than US\$40/ kg U
Paramarginal Demonstrated Resources	RAR recoverable at US\$40–80/ kg U
Submarginal Demonstrated Resources	RAR recoverable at US\$80–130/ kg U
Economic Inferred Resources	Inferred Resources (IR; formerly Estimated Additional Resources Category 1 – EAR-1) recoverable at less than US\$40/ kg U
Subeconomic Inferred Resources	IR recoverable at US\$40–130/ kg U

Australia's EDR were estimated to be 675 000 t U, a decrease of 14 000 t U compared to the previous year. This decrease was due mainly to production from the three operating mines (Ranger NT; Olympic Dam SA; Beverley SA), together with reassessments of the ore reserves and mineral resources for Olympic Dam deposit.

Approximately 97% of Australia's total uranium resources in EDR are within the following six deposits:

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

Accessible EDR

Approximately 11% of uranium EDR is inaccessible for mining. Western Australian State Government policies prohibit uranium mining for nuclear purposes from any mining leases granted after June 2002. The uranium deposits in WA are classified as inaccessible resources. Inaccessible resources also include those deposits in the Alligator Rivers region where the mining leases are too small to accommodate the proposed mine and treatment plant facilities and water retention ponds. These lease areas cannot be increased because they are surrounded by Kakadu National Park.

JORC Reserves

EDR is the sum of JORC Code reserves categories plus those resources in measured and indicated categories which Geoscience Australia considers will be economic over the long term. In 2003, JORC Code reserves of 435 000 t U account for approximately 72% of AEDR.

World Ranking

Australia has the world's largest resources of uranium in RAR recoverable at <US\$40/kg U (equates to EDR), with 39% of world resources in this category. Other countries with large resources include Canada (17%), Kazakhstan (16%) and South Africa (7%) (Source: OECD/NEA & IAEA).

Exploration

Uranium exploration expenditure in Australia for calendar year 2003 was \$6.38 million, compared with \$5.34 million in 2002. Exploration was undertaken only in the Northern Territory and South Australia, the main areas and deposit types targeted were:

- **Arnhem Land (NT):** exploration for unconformity-related deposits in Palaeoproterozoic metasediments below a thick cover of Kombolgie Sandstone,
- **Frome Embayment (SA):** exploration for sandstone type deposits in Tertiary sediments,
- **Gawler Craton and Stuart Shelf area (SA):** exploration for breccia complex type copper-uranium-gold deposits in hematite-rich breccias hosted by Mesoproterozoic granites, volcanics and metasediments.

Heathgate Resources continued exploration in areas surrounding the **Beverley** mine (SA). A total of 70 holes were drilled during the year in areas ranging from 100 km north to 30 km south of the mine. Further close-spaced drilling is planned in an area immediately south of Beverley.

Southern Cross Resources completed an airborne electro-magnetic survey over exploration tenements in the Frome Embayment in order to locate buried palaeochannels 70–120 m below surface. Exploration drilling was carried out within these palaeochannels. In 2004, Southern Cross Resources announced the discovery of a new zone of low-medium grade uranium mineralisation in an area of the Yarramba palaeochannel approximately 1.5 km north-west of the Honeymoon deposit. The new zone (known as **Brooks Dam** prospect) has been tested by drilling over a distance of 1 km along the palaeochannel. Drill intersections through the mineralisation are reported in terms of thickness multiplied by grade, ie. in units of m% U₃O₈. Intersections within the new zone range from 0.23 to 0.83 m%. In comparison, the Honeymoon deposit averages 0.84 m%.

The zone is open to the north and south and the company considers that it may extend as far south as the main **Honeymoon** deposit. Additional drilling is required before an estimate can be made of the mineral resources for this zone.

Grades and thicknesses of mineralised intersections were measured using a down-hole Prompt Fission Neutron probe which the company recently purchased. This gives more reliable uranium grades than the gamma-ray probes normally used for evaluating this type of sandstone-hosted uranium deposit.

During 2003, **Minotaur Resources** continued exploration drilling at the **Prominent Hill** Cu-Au-U deposit, approximately 150 km northwest of Olympic Dam. The best intersection was 130 m averaging 1.41% Cu, 0.43 g/t Au, 82 ppm U within hematite-sandstone breccia. This interval included 56 m averaging 2.02% Cu, 0.64 g/t Au, 115 ppm U.

Mineralisation at Prominent Hill is known over a strike length of more than 600 m. Drilling confirmed the presence of two mineralised breccia zones in the western part of the deposit. The southern breccia, which is the wider of these two zones, ranges up to 40 m wide. The best drill intersection in the southern breccia was 66 m averaging 2.54% Cu and 0.43 g/t Au, commencing at a drill hole depth of 188 m.

The geological setting and style of mineralisation are broadly similar to the Olympic Dam deposit, however the average uranium grades from drill intersections in Prominent Hill mineralisation are much lower than for Olympic Dam which averages 400–500 ppm U.

Production

Production for 2003 from Australia's three uranium mines were Ranger (5065 t U₃O₈), Olympic Dam (3176 t U₃O₈), and Beverley in situ leach operations (689 t U₃O₈). Total production for 2003 was 8931 t U₃O₈ (7573 t U), 10% higher than for 2002.

Industry Developments

Ranger: Ranger mine achieved record production for 2003. Mining at Ranger No. 3 Orebody is expected to continue until at least 2009, after which the pit will be used for the storage of tailings. Production from stockpiled ore will continue until at least 2011.

Olympic Dam: During 2003, a total of 9.0 Mt ore was mined at Olympic Dam. The processing plant treated 8.4 Mt ore with an average grade of 2.4% Cu and 0.63 kg/t U₃O₈ to produce 160 080 t copper and 3176 t U₃O₈. Reconstruction of both the copper and uranium solvent extraction plants (previously destroyed by a fire in late 2001) was completed in 2003. The new uranium solvent extraction plant was operating at planned production rates by June. As a result, production rates increased during the year and it is anticipated that the plant will operate at full capacity of 235 000 t copper and 4500 t U₃O₈ during 2004.

WMC Resources commenced a study to determine whether there should be a major expansion of the Olympic Dam mine. The main investigations and work programs for this study include:

- an additional 72 km of drilling to evaluate the undeveloped southern deposit,
- assessment of mining and processing methods for the southern deposit,
- environmental studies, including the scoping of a new Environmental Impact Statement,
- a detailed investigation of options for future water and energy supplies to the operation.

Studies to date have indicated that by extending underground mining, Olympic Dam could increase capacity from the current level of 235 000 t copper to 350 000 t copper per year. The company considers that open pit mining, when added to continuing underground operations, could increase copper production to more than 500 000 t per year, with associated increases in uranium production. The development study is scheduled to be completed in 2006.

A major drilling campaign continued during 2003 to explore and delineate the southern orebody, the results of which will be used to evaluate the various mining options as part of the study.

Beverley: In situ leach (ISL) mining was extended from the North Orebody into the much larger Central Orebody during 2003. Plant capacity was expanded to include a third train of ion exchange columns. Installation of the main pipelines (trunklines) connecting the plant to the Central Orebody was completed, and lateral pipelines and wellhouse connections were installed. Production rate increased steadily during the year and by early 2004, production reached an annualised rate of 1000 t U₃O₈, the licensed capacity of the plant.

During 2003, Commonwealth and South Australian Government agencies considered a proposal from the company to expand the Beverley operations to produce up to 1500 t U₃O₈ per year. The company was required to undertake groundwater modelling studies to determine the hydrological impacts on the Beverley aquifer which may result from increased rates of disposal of liquid wastes from the ISL operations. Reports were submitted to Government agencies for assessment and a final decision is expected in early 2004.

Jabiluka: During 2003, the mineralised stockpile was placed in the underground mine openings and the 1.2 km decline was backfilled with waste rock. The project site remains on long-term care-and-maintenance.

Honeymoon: In late 2001, Southern Cross Resources received Commonwealth and State environmental clearances to develop the Honeymoon ISL uranium project (SA). However, development is currently on hold pending an improvement in market conditions.

Western Australia: The Western Australian State Government has recently introduced new legislation to prohibit the mining of uranium for nuclear purposes from any mining lease granted after June 2002. The policy is now a draft Bill called the *Uranium Mining Prohibition Bill 2004*. There are no uranium mines in Western Australia, but there are large deposits at Kintyre and Yeelirrie.

In March 2004, the Western Australian Government and WMC Resources reached agreement to terminate the *Uranium (Yeelirrie) Agreement Act 1978*. This Act was legislated in 1978 to facilitate the possible construction of a uranium and vanadium treatment plant at Yeelirrie.

Below: Beverley in situ leach uranium mine, South Australia. Ion exchange plant with main trunkline (pipeline) which extends from the plant to the in situ leach wellfield (top right corner of photo). Recently constructed evaporation ponds are blue areas adjacent to the plant.
(Heathgate Resources Pty Ltd)

Right: Wellfield at Beverley in situ leach uranium mine. Main trunkline with injection wells and recovery wells.
(Heathgate Resources Pty Ltd)



Vanadium

Vanadium is used in metal alloys with iron to produce high strength steel which has a wide range of uses including the manufacture of axles and crankshafts for the automobile industry, and jet engines for the aircraft industry. Mine production accounts for only approximately 20% of annual world production of vanadium, the majority of world production (80%) is a by-product from reprocessing of steel slags, oil refining, and the uranium enrichment industry.

Resources

66

For 2003, Australia had no EDR of vanadium due to the closure of the Windimurra mine and processing plant, 75 km southeast of Mount Magnet, WA. Xstrata AG reported that the project was not viable in 2002 (refer 'Industry Developments' below) because of continuing low metal prices in recent years. The large reserves for Windimurra, which were formerly considered to be economic (prior to 2002), have been reclassified into paramarginal resources.

Australia currently has very large tonnages of vanadium in paramarginal and submarginal resources within deposits in the Yilgarn region (Windimurra, Gabanintha) and Pilbara region (Balla Balla, Don Well) of WA.

Historically, prices for vanadium pentoxide (V_2O_5) have varied over a wide range, and as a consequence, Australia's EDR has varied with price trends.

Exploration

There was no exploration for vanadium during the year.

Production

In 2003, Australia produced 694 t V₂O₅ flake (389 t V) valued at \$4.665 million, all of this being from Windimurra mine in its final months of operation prior to suspension of production.

Most of the world's mine production of vanadium for 2003 was from China (58%), South Africa (25%) and Russia (15%).

Industry Developments

Production at **Windimurra** mine was suspended in February 2003, and the mine was permanently closed in May 2004. **Xstrata AG** declared that operations at the mine and processing plant were not profitable in 2002 (Xstrata Annual report 2002). The profitability of Windimurra was strongly affected by two factors: low prices for V₂O₅, and the US dollar/Australian dollar exchange rate. Despite increasing demand in recent years, the vanadium market remained in oversupply, which kept market prices for both V₂O₅ and ferrovanadium (FeV), at low levels. Prices for V₂O₅ were less than US\$1.50 per pound throughout the period 2000 to 2002, and US\$1.70–\$1.80 for 2003. During the period in which the Windimurra feasibility study was being investigated (1998 and 1999) prices ranged from US\$4 to more than US\$6 per pound.

Xstrata also operates large vanadium mining/metallurgical operations at Rhovan and Vantech in South Africa.

During 2004, the WA State Government initiated an inquiry into the closure of the Windimurra operations. The inquiry will also investigate the management of vanadium resources at Windimurra, and the impact of management on market price of vanadium and State resources. A report on the inquiry is due to be released by the end of 2004.

During the year, **Greater Pacific Gold NL** carried out metallurgical test work to determine the commercial feasibility of the process technology for extraction of V₂O₅ and titanium from the **Gabanintha** project (40 km SE of Meekatharra). Test work was carried out on drill core samples recovered from large diameter holes which were drilled during the year. The holes were all drilled to a depth of 50 m. Results to date show that the degree of upgrading of the titaniferous minerals was limited by the fine-grain size and intergrowth with iron oxides.

Zinc, Lead, Silver

The construction and appliance manufacturing industries use large amounts of **zinc**, mainly as coatings on steel beams, sheet steel and vehicle panels in the automotive industry. It is also used in alloy die cast products, zinc pigments, zinc salts, zinc oxide as additives to rubber and for zinc chemicals in agriculture, and for wrought or rolled zinc products.

The widespread occurrence of **lead**, coupled with its relatively simple extraction, malleability and resistance to corrosion, have made it useful to humans since at least 5000 BC. In deposits mined today, lead (in the form of galena, PbS) is usually associated with zinc, silver, and is extracted as a co-product of these metals. More than half of the lead used today comes from recycling, rather than mining. The largest use is in batteries for vehicles and communications. Less important uses include cable sheathing, solder, casting alloys, chemical compounds, ammunition, glass in TV and computer screens for radiation protection, and ceramics. Its use as a petrol additive has declined significantly with the gradual introduction of lead-free petrol worldwide. New uses for lead could be in large storage batteries used for load-levelling of electrical power and in electric vehicles.

The relative scarcity, attractive appearance and malleability of **silver** has made it suitable for use in jewellery, ornaments and silverware since before ancient Roman times. Its extensive use in coins throughout history has declined over the last forty years. In Australia, the 1966 fifty-cent piece was

the last coin in general use to contain silver (80% silver, 20% copper). Silver is mined and produced mainly as a co-product of lead, zinc and, to a lesser extent, copper and gold. Today, photographic paper and film, followed by the electronics and jewellery/tableware industries are the most important users of silver. Demand for silver as an anti-bacterial agent is likely to double over the next few years as its use increases in water treatment (as an ioniser with copper in domestic swimming pools) and for biocide and bacteriostatic activity in plastic and textiles formulations. Silver based biocides are also being tested as a replacement for arsenic-based preservatives in wood treatment.

Resources

ZINC

Australia's EDR for zinc increased by 5% to 34.8 Mt in 2003. Queensland remained pre-eminent, its EDR increasing from 17.81 Mt to 20.5 Mt and increased its share of the total EDR to 62%. The rise in EDR was predominantly affected by the reclassification of resources at Century and Mt Isa while other resources remained steady. The Northern Territory at 9.9 Mt had the second largest EDR and its share of national EDR was 28.5% compared to 31.1% in 2002. New South Wales had the third largest EDR with 2.8 Mt (3.0 Mt in 2002). This decrease was primarily due to depletion of resources through production. Western Australia's EDR fell again to 0.9 Mt, (1.5 Mt in 2002), mainly due to production depleting Golden Grove resources, while Victoria remained unchanged at 0.4 Mt. Tasmania's EDR increased to 0.3 Mt (0.26 Mt in 2002), due to an increase at Rosebery.

Paramarginal demonstrated resources of zinc fell by 29% from 8.79 Mt to 6.26 Mt due to reclassification of the Mt Isa and McArthur River resources. Submarginal demonstrated resources fell from 16.3 Mt to 16.0 Mt over the year. These global variations are attributed to relatively small changes in most states and the Northern Territory in both categories.

Total inferred zinc resources increased by 33% to 31.8 Mt in 2003 following the addition of 11 Mt to the Mt Isa resource.

LEAD

Australia's EDR of lead increased in 2003 by 11% to 19.3 Mt of contained lead. Queensland retained the premier ranking with its EDR increase from 9.1 Mt in 2002 to 10.2 Mt in 2003, representing 53% of total EDR. This was due to increased resource definition at Mt Isa and Century. The Northern Territory decreased slightly from 5.75 Mt to 5.53 Mt EDR, or 39% of the national total. New South Wales recorded another drop in EDR from 1.8 Mt in 2002 to 1.7 Mt in 2003, due to depletion of resources through production at Broken Hill and Elura. EDR in Western Australia increased by 72% to 1.8 Mt due to reclassification of resource at the Magellan deposit. Tasmania's EDR rose by 0.01 Mt (10%) to 0.09 Mt due to a minor increase in Rosebery resources.

Australia's paramarginal demonstrated resources of lead are 1.9 Mt. Submarginal demonstrated resources totalled 9.2 Mt. The aggregate sub-economic resources were 7% more than in 2002.

Total inferred lead resources rose by over 1.5% to 24.9 Mt in 2003 following an increase in resources at the Mt Isa deposit.

SILVER

Australia's EDR of silver increased in 2003 by 7% to 42.9 kt of contained silver. Queensland remained pre-eminent and its EDR rose from 29.1 kt to 32.2 kt, and its share of the total EDR rose from 73% to 75% in 2003. The increase was mainly a result of reclassification of the Mt Isa and Cannington resources, which offset decreases at Hilton. The Northern Territory at 4.8 kt again had the second largest EDR and its share of national EDR was marginally down to 11.1% compared to 12.6% in 2002. South Australia had the third largest EDR with 2.4 kt (unchanged from 2002) and was followed by New South Wales at 2.2 kt (unchanged from 2002), with minor increases at Broken Hill and Elura offsetting decreases at Tritton deposit. Western Australia was next with 0.8 kt (0.4 kt in 2002), followed by Tasmania with 0.31 kt (0.26 kt in 2002), due to minor increases at Rosebery, with Victoria unchanged at 0.28 kt.

Paramarginal demonstrated resources of silver decreased from 10.7 kt to 9.8 kt and submarginal demonstrated resources also decreased slightly from 12.1 kt to 11.8 kt over the year. These global variations are attributed to small decreases in Queensland's paramarginal resources due to reclassification at Mt Isa and New South Wales' submarginal resources at Broken Hill and Elura.

Total inferred silver resources had a large increase to 42.7 kt in 2003 following an increase of resources at Mt Isa's open pit mine.

Accessible EDR

All EDR of lead, zinc and silver are accessible for mining.

JORC Reserves

Approximately 65% of Zinc AEDR, 54% of lead AEDR and 62% of silver AEDR comprise JORC Code reserves. The remaining represents resources assessed by Geoscience Australia as being economically recoverable from industry's measured and indicated categories of mineral resources, as defined under the Code.

The EDR/production ratio for zinc is 24 years and the ore reserve/production ratio is 15 years. The EDR/production ratio for lead is just under 28 years and the ore reserve/production ratio is 15 years. The EDR/production ratio for silver is 23 years and the ore reserve/production ratio is 14 years.

Exploration

Exploration spending on zinc-lead-silver in 2003 was \$29.7 million, \$6.4 million less than in 2002. The 2003 expenditure was about 22% of total base metal expenditure of \$134.6 million compared to 27% in 2002.

At the old **Pinnacles** mine at Broken Hill, drilling by **Pinnacles Mines Pty Ltd** intersected mineralisation including 6.4 m at 11.16% Zn, 1.38% Pb and 0.63 g/t Au, and 2.5 m at 12.58 g/t Au.

Kagara Zinc Ltd's drilling at **Montevideo** near Chillagoe (Qld) returned a 38.1 m intersection of 7.0% Zn including 13.8 m at 11.0% Zn. Kagara also reported further good intersections from the **Balcooma** project, near Greenvale (Qld). In the Upper Lens 4.6 m at 28.8% Pb and 4.53 g/t Au and 4.0 m at 4.8% Pb and 9.4 g/t Au were reported. High-grade copper intersections were 8.1 m at 16.8% Cu, and 8.0 m at 13.45% Cu and 7.3% Pb.

Glengarry Resources Ltd reported highly anomalous silver, cobalt and tungsten intersections at its **Diamantina** project south of Mt Isa. A 1 m intersection at 84.6 g/t Ag, 0.32% Co and 470 ppm W was recorded at 47 m at the end of the hole.

Tectonic Resources NL completed infill drilling of the shallower portion of the Harbour View and Harbour View North prospects at the **Kundip** Project in Western Australia. Results included 7m averaging 11.6g/t Au, 1.1% Cu from 35m, 6m averaging 9.72g/t Au, 1.14% Cu, 9 g/t Ag from 56 m, and 3 m averaging 8.85g/t Au, 5.31% Cu, 21 g/t Ag from 89m. Following these results a third deep RC and diamond drilling program of about 23 holes for a total of 3200 m was commenced with the aim of better defining the high-grade deeper resource. Concurrent with this work detailed metallurgical testing is to be undertaken confirming the required treatment path for economic extraction of the gold, copper and silver. The completed program has now defined the shallow portions of the structures to sufficient density that a measured resource can be estimated. Upon completion of the deep drilling program a combined oxide and sulphide resource will be announced.

Production

In 2003, Australian mine productions were 1.479 Mt zinc, 0.688 Mt lead and 1.868 kt silver. These figures represent a slight increase for zinc (up 0.01 Mt), no change for lead and a slight decrease for silver (down 0.23 kt) compared to 2002. Cannington is the world's largest and lowest cost silver and lead producer; it produced almost 233 kt of lead and 35.5 Mozs of silver in 2003. Century had the largest zinc output at 503 kt.

World Ranking

Australia has the world's largest EDR of zinc (17%) and lead (25%), and the second largest EDR of silver (15%), behind Poland (18%).

In terms of production, Australia ranks first for lead, second for zinc after China and third for silver after Mexico and Peru.

Industry Developments

Inmet Mining Corporation and **Pilbara Mines Ltd** announced an initial resource for the Jaguar deposit at **Teutonic Bore**, WA. Pilbara subsequently acquired Inmet's share of the project and announced a new resource of 1.72 Mt at 3.6% Cu, 11.9% Zn and 127 g/t Ag. The main drill intersections were 3.67 m at 7.36% Cu, 10.95% Zn and 233 g/t Ag, and 5.03 m at 4.36% Cu, 7.49% Zn and 144 g/t Ag.

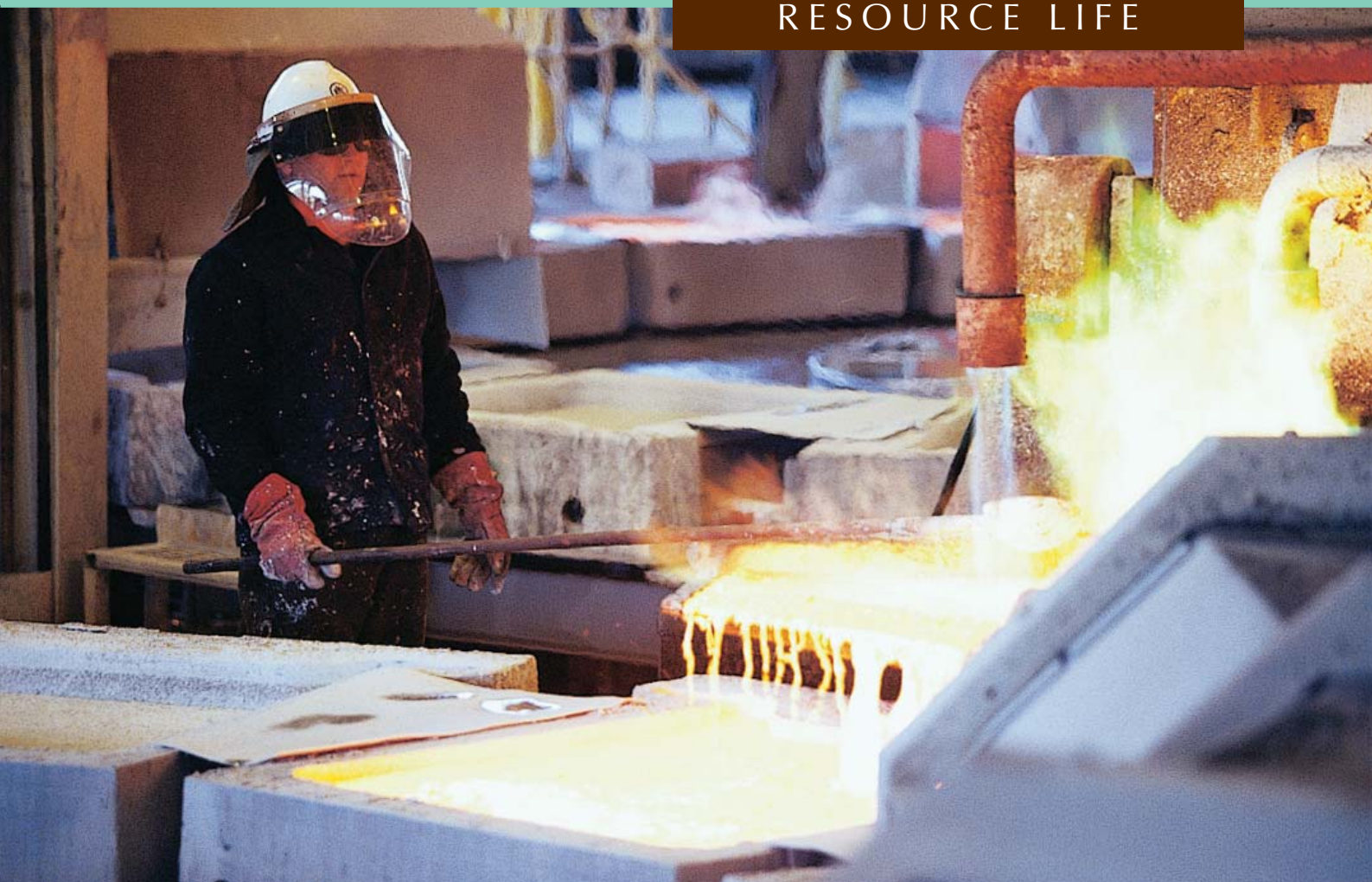
Consolidated Broken Hill purchased Pasminco's **Elura** mine (now called **Endeavour**) in New South Wales for a reported \$22 million and plans to increase ore production to 1.4 Mtpa. A revised mine plan has enabled a substantial increase in reserves to 11.6 Mt at 8.3% Zn, 5.1% Pb and 50 g/t Ag. The purchase of Elura and failure to acquire Pasminco's assets at Broken Hill has resulted in Consolidated concentrating its attention on Elura ahead of its **Rasp** project at Broken Hill.

Kagara Zinc will spend \$7.5 million on an expansion of the treatment plant at the **Mount Garnet** operation in Queensland. The work will increase annual concentrate capacity from 90 000 t to 148 000 t. In addition they will add a 20 000 tpa copper circuit to process supergene ore from **Balcooma**. At Balcooma, Kagara reported further encouraging drill intersections including 10 m at 15.9% Pb and 16.1% Zn and a high-grade copper intersection of 16.1 m at 12% Cu.

The receivers of **Western Metals** sold the company's **Lennard Shelf** zinc-lead operations to **Teck Cominco** for \$26 million. While the acquisition will add to Teck's production capacity the operations will remain closed pending improved metal prices or better exchange rates.

Xstrata is continuing work on a feasibility study investigating the possible expansion of operations at the **McArthur River** mine, NT, and the possible use of the Albion technology.

PRODUCTION AND
RESOURCE LIFE



Pouring copper anodes, Olympic Dam operations, South Australia.
(WMC Resources Ltd)

Production and Resource Life

Australia's production of selected mineral resources, concentrates and metals for 2003–04 are presented in Table 4. Australian Bureau of Agricultural and Resource Economics (ABARE) reported that minerals and energy commodities for which mine production rose significantly in 2003–04 compared with 2002–03 were manganese ore (up 24%), magnesite (23%), iron ore (12%), brown coal (5%) and black coal (3%). More than half of Australia's major mineral and energy commodities recorded production decreases in 2002–03, the most substantial being for tin (down 77%), rutile concentrates (26%), diamonds (24%), zinc (11%), copper (10%) and gold (6%).

ABARE reported that Australia's export earnings from mineral resources fell to \$52.2 billion in 2003–04, a decrease of \$2.8 billion or 5% compared with 2002–03. This weaker performance mainly reflected lower prices for about 80% of the minerals and energy commodities exported, largely as a result of the strong Australian dollar in 2003–04.

To sustain these export earnings and maintain Australia's position as one of the world's leading minerals producers, resources need to be discovered and developed for production at rates sufficient to meet demand. To facilitate assessment of the future supply capability of identified resources, ratios of AEDR to current mine production have been provided in the commodity reviews above, as an indicator of the resource life. This indicator can change quite rapidly, for example with significant changes in production rates and metal prices. Iron ore provides a good example of how resource life can vary markedly over a short period: increasing production in response to growing demand from Asia, has been a major factor contributing to the iron ore resource life halving from 125 years in 1995 to 60 years in 2003.

AEDR of the other main bulk mineral commodities can sustain current rates of mine production on average for the following approximate periods years: black coal 100 years, bauxite 90 years, manganese ore 25 years, and brown coal 450 years. Ratios of AEDR to current mine production for other minerals indicate a resource life of: nickel 120 years, copper 50 years, ilmenite 85 years, rutile 90 years and zircon 50 years.

The resource lives for gold (just under 20 years at current rates of production), lead (less than 30 years) and zinc (less than 25 years) are amongst the lowest. Gold price increases over many years have contributed to increasing expenditure on gold exploration since 1980. Despite the fact that there has been a progressive increase in Australia's EDR of gold since the mid-1980s, there is still a need for ongoing successful gold exploration in the short and medium terms to discover sufficient resources to maintain gold as one of Australia's main export commodities.

Similarly, there is a need for significant new discoveries of lead and zinc in the not too distant future to sustain production of these commodities at current levels beyond the next 25 years, when almost all existing base metal mines will have closed. In addition, there is usually a period of about 10 years between the initial discovery of a deposit and the commencement of production for large lead-zinc projects. The success of fine grinding technology has allowed the economic extraction of base metals from the McArthur River and Mount Isa deposits and resulted in increases in EDR. However, there is a need to discover and develop a high quality, metallurgically attractive lead-zinc deposit.

TABLE 4. Australian production and exports of selected mineral products 2003–04.

Commodity	Production	Exports	Export value \$ million
Aluminium			
Bauxite (Mt)	56.316		173
Alumina (Mt)	16.796	13.538	3767
Aluminium (Mt)	1.880	1.546	3435
Coal			
Black raw (Mt)	362.22		
Black saleable (Mt)	285.86	219.46	10 893
Brown	67.86		
Copper			
Ores and concentrates (kt)	2340	1288	1237
Refined primary (kt)	458	301	929
Diamond (kc)	24 310	26 667	531
Gold			
Mine production (t)	260		
Refined (t) ^(a)	397	315	5510
Iron and Steel			
Ore and Pellets (Mt)	222.28	194.853	5216
Iron and steel (Mt)	9.445	3.818	2049
Lead			
Ores and concentrates (kt)	960	417	385
Refined (kt)	247	231	199
Bullion (kt)	143	113	139
Manganese			
Ores and concentrates (kt)	3062	2603	385
Mineral sands			
Ilmenite concentrates (kt)	1925	782	82
Rutile concentrates (kt)	154	146	95
Synthetic rutile (kt)	696	470	255
Titanium dioxide pigment (kt)	196	165	399
Zircon concentrates (kt)	451	426	240
Nickel			
Concentrate (kt Ni)	185		
Refined (kt)	234 ^(b)	215	3088 ^(c)
Uranium (t U ₃ O ₈)	9538	9099	364
Zinc			
Ores and concentrates (kt)	2536	1855	673
Refined (kt)	499	396	557

Notes for Table 4

Source: Australian Mineral Statistics, ABARE, June quarter 2004
 Australian Commodities ABARE, September 2004

t = tonnes; kt = 10³t; Mt = 10⁶t; kc = 10³ carats

(a) Includes primary and secondary gold of Australian and overseas origin

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

(c) Sum of all nickel product export values.

EXPLORATION



Exploration for manganese ore in the East Pilbara region, Western Australia.
(Consolidated Minerals Ltd)

Expenditure

Mineral exploration expenditure for a range of commodities is collected quarterly by ABS. The following discussion is based on the survey data for 2002–03 (year ended 30 June 2003) and the first two quarters of 2003–04. Differentiation of exploration spending into commodity groups prior to 1980 is based largely on a breakdown of ABS totals by Geoscience Australia.

Australian mineral exploration expenditure rose by 11.4% to \$732.6 million in 2002–03 according to the ABS. This was the highest financial year current dollar amount since 1998–99. Spending for calendar year 2003, based on the sum of the ABS four quarterly figures, rose by just over \$57 million to \$735.3 million.

Gold was again the principal commodity sought and its share of total exploration remained steady at 51.7% in 2002–03. While retaining its dominant position, exploration expenditure on gold rose by \$47.1 million to \$378.4 million (Fig. 2, Table 5) its highest level since 1998–99. Although Western Australia remained dominant in the search for gold its share of spending fell slightly to 70% (\$265.6 million). For reasons of confidentiality of data collected for either Victoria or the Northern Territory, or both, ABS has not published exploration expenditures on individual commodities for those jurisdictions, however aggregate spending in the two was \$59 million (15.6% of total spending). In other States, spending on gold was: Queensland \$24.3 million (6.4%), New South Wales \$19.9 million (5.3%), South Australia \$8.3 million (2.2%) and Tasmania \$1.4 million (0.3%).

FIGURE 2. Australian mineral exploration expenditure by commodity since 1992–93
(Source: ABS).

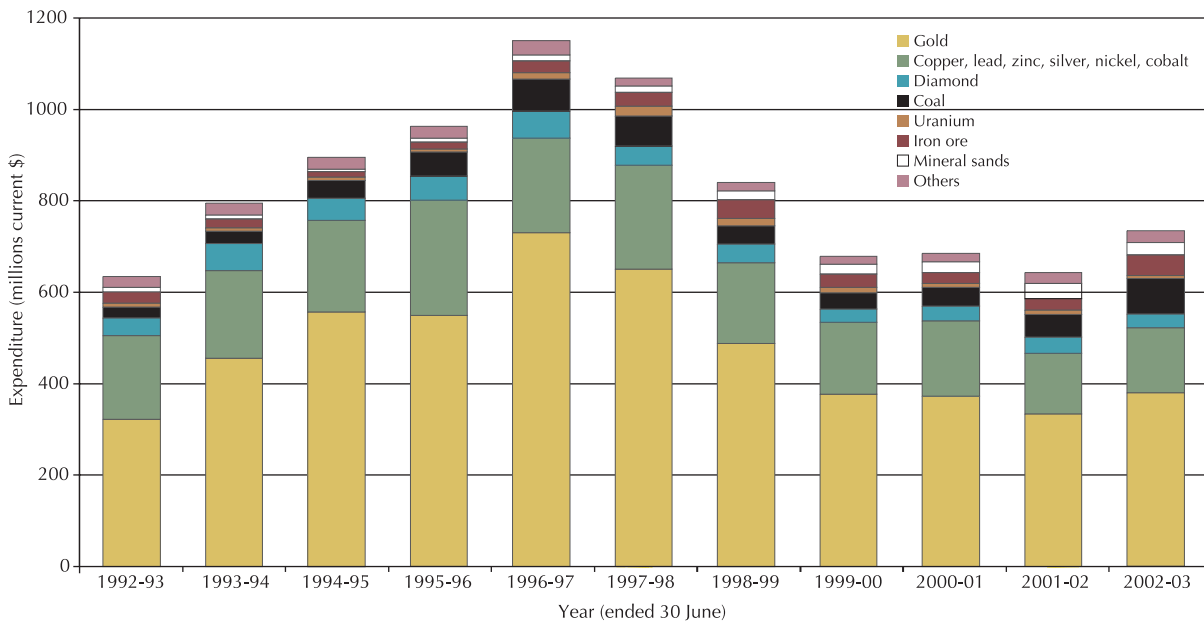


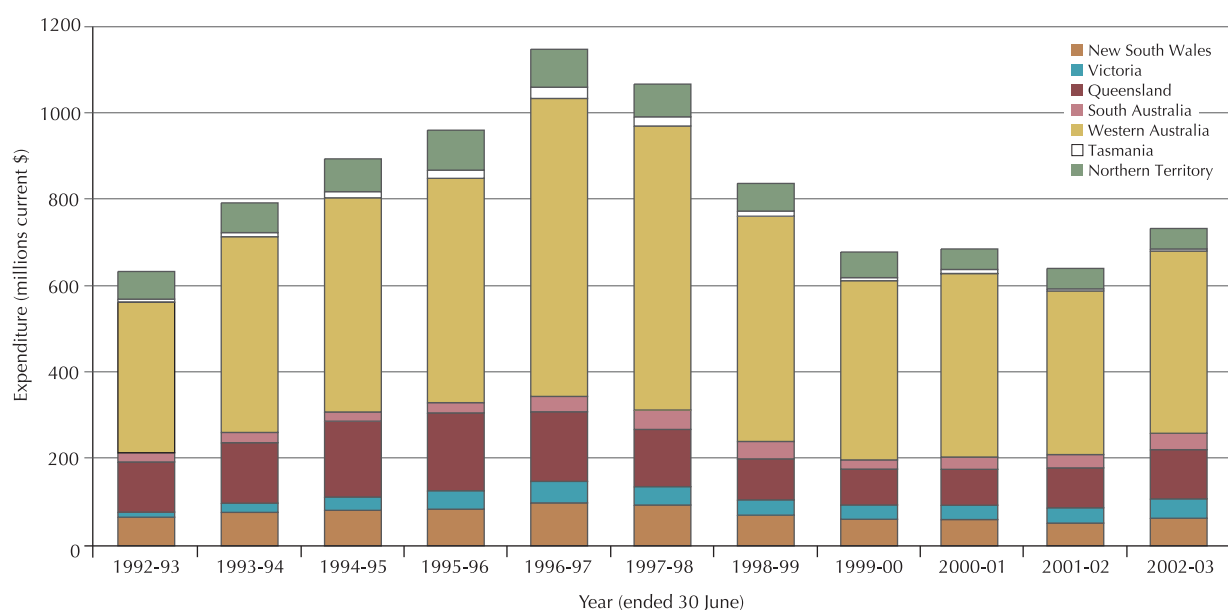
TABLE 5. Australian mineral exploration expenditure by commodity, 2001–02 and 2002–03.

Commodity	Exploration Spending (\$ million)		Change (\$ million)	Proportion of Australian Total Exploration Spending		Change % points
	2001–02	2002–03		2001–02	2002–03	
Gold	331.3	378.4	47.1	51.7	51.7	0.0
Base Metals	132.9	142.0	9.1	20.7	19.4	-1.3
Diamond	35.4	29.8	-5.6	5.5	4.1	-1.4
Coal	50.3	77.9	27.6	7.9	10.6	2.7
Iron Ore	25.2	44.5	19.3	3.9	6.1	2.2
Mineral Sands	33.2	27.3	-5.9	5.2	3.7	-1.5
Uranium	8.8	6.9	-1.9	1.4	0.9	-0.5
Others	23.4	25.8	2.4	3.7	3.5	-0.2

After a fall in 2001–02, the combined spending on base metal (copper, lead, zinc, silver, nickel, cobalt) exploration recovered to increase by 6.8% to \$142 million. ABS data for base metals exploration shows that spending on copper exploration fell by \$1.9 million to \$39.7 million in 2002–03. Zinc-lead-silver spending at \$36.6 million was \$1.0 million less than in 2001–02. However, in response to the intense world-wide interest in nickel, the spending on exploration for nickel-cobalt rose by almost 23% to \$65.9 million. Because ABS is unable to publish comprehensive jurisdiction-based data for reasons of confidentiality a meaningful review of State spending is not possible, however, it should be noted that 82% of spending on nickel-cobalt exploration was in Western Australia where attention was focussed on the search for nickel sulphides.

Exploration spending on coal and iron ore increased substantially in 2002–03. Coal spending rose by almost 55% to \$77.9 million, surpassing the previous high of \$70.5 million recorded in 1996–97. Iron ore exploration spending increased by 76.6% to \$44.5 million which was the highest expenditure reported in the last decade. In contrast, spending was lower on the search for diamond, mineral sands and uranium. Mineral sands exploration retreated from the record level of 2001–02 with a fall of 17.8% to \$27.3 million which, despite the fall, was still the second highest level recorded. Diamond exploration fell by 15.8% to \$29.8 million the equal lowest level for the last decade while uranium spending at \$6.9 million was down by 21.6% to the lowest level in the decade. The share of total spending held by gold and base metals combined was slightly lower at 71% compared to 72% in 2001–02 and sharp reduction from the 78% held in 2000–01.

Exploration spending rose in all jurisdictions in 2002–03 with increases ranging from 1.2% in the Northern Territory to 36% in Victoria. Western Australia remained the main destination for exploration with \$423.6 million spent, an increase of 11.2%, and accounted for 57.8% of total exploration spending which was slightly lower than the 59.5% recorded in 2001–02 (Fig. 3, Table 6). Although Queensland again had the second highest expenditure, attracting \$114.0 million it registered a substantial 23% increase over 2001–02 and had 15.6% of total Australian spending. In New South Wales, spending totalled \$58.8 million which was \$10.5 million (21.7%) higher than the previous year and the Northern Territory recorded a 1.2% increase to \$49.0 million. Victoria had a 36% increase in spending to \$46.1 million, the highest level since 1996–97 and had 6.3% of total spending. South Australian spending continued the recovery started 2000–01 as it rose by 14.3% to \$36.7 million. Tasmanian spending recovered a small proportion of the substantial loss recorded last year with a 7.5% rise to \$4.3 million.

FIGURE 3. Australian mineral exploration expenditure by State since 1992–93 (Source: ABS).

TABLE 6. Australian mineral exploration expenditure by State, 2001–02 and 2002–03.

State	Exploration Spending (\$ million)		Change (\$ million)	Proportion of Australian Total Exploration Spending		Change % points
	2001–02	2002–03		2001–02	2002–03	
Western Australia	381.1	423.6	42.5	59.5	57.8	-1.7
Queensland	92.7	114.0	21.3	14.5	15.6	1.1
New South Wales	48.3	58.8	10.5	7.5	8.0	0.5
Northern Territory	48.4	49.0	0.6	7.6	6.7	-0.9
Victoria	33.9	46.1	12.2	5.3	6.3	1.0
South Australia	32.1	36.7	4.6	5.0	5.0	0.0
Tasmania	4.0	4.3	0.3	0.6	0.6	0.0

In 2002–03 constant dollar terms, exploration spending recorded an increase of 11.4% in the 2002–03 year. This was the first annual increase since the peak year of 1996–97 (Fig. 4a) but spending remained at a relatively low level compared to the last two decades.

FIGURE 4A. Australian mineral exploration expenditures in constant 2002–03 dollars (Based on ABS data deflated by Consumer Price Index).

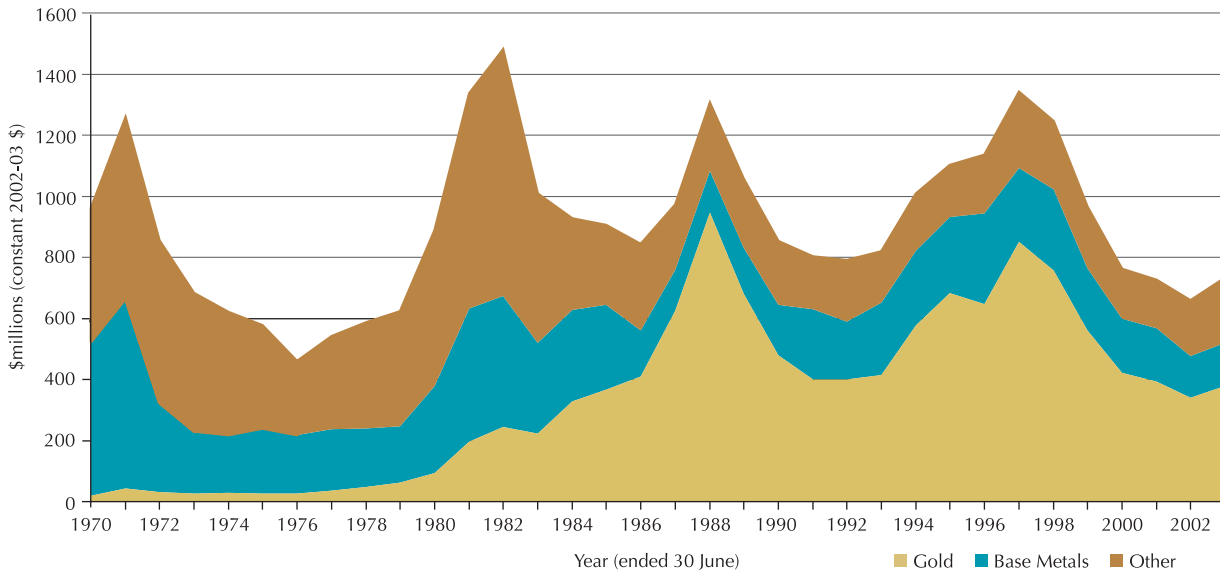
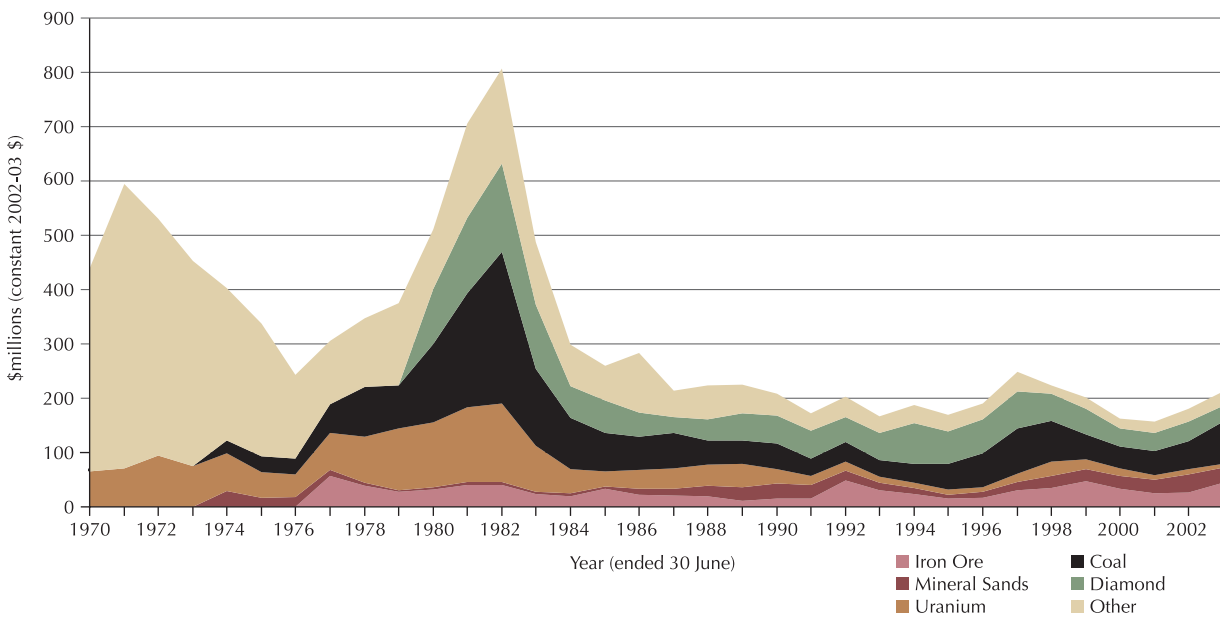


FIGURE 4B. Australian mineral exploration expenditures for commodities grouped as 'others' in Figure 4A. Expenditures in constant 2002–03 dollars (Based on ABS data deflated by Consumer Price Index).



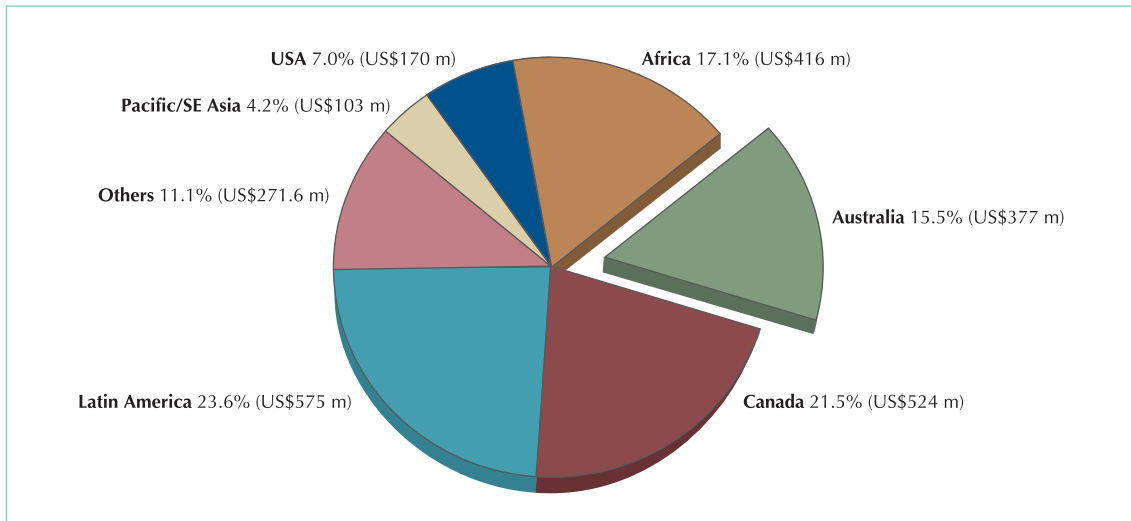
Exploration Drilling

In 2002–03, according to ABS, exploration drilling rose by 6.7% to 5.16 million metres, an increase of 324 000 m. Of the total metres drilled, 31.5% was in 'Production Areas', which was a greater proportion than the 29% of the previous two years.

World Exploration

The Metals Economics Group's (MEG) world survey of non-ferrous mineral exploration budgets for 2003 reported an increase of 26% to an estimated total budget of US\$2.4 billion. For exploration in Australia, budgets of respondents to the MEG survey rose by 11% to US\$339.3 million. This increase was less than in other mining nations, so Australia's share of the world budgets fell to 15.5% (Fig. 5) from 17.6% in 2002. Canada was again the leading country with 21.5% of world budgets.

FIGURE 5. Distribution of world mineral exploration budgets, 2003
 (Source: Metals Economics Group, Canada).



According to the MEG data, 61% of 2003 exploration budgets for Australian-based companies were directed to exploration in Australia. The MEG survey included 233 companies with exploration budgets of more than US\$100 000 that were exploring in Australia, an increase of 12 over 2002. Budgets for Australian exploration were directed mainly to gold (US\$209.3 million), base metals (US\$83.5 million) and diamonds (US\$15.9 million). Australian grassroots exploration budgets are dominated by the search for gold (55% of total budgets).

Outlook for Exploration

Australian mineral exports are at near record levels with the Australian Bureau of Agricultural and Resource Economics (ABARE) predicting export earnings from Australia's mineral resources to rise by 11% to \$58.3 billion in 2004–05. ABARE expects world consumption of all major mineral (and energy) commodities to increase in 2004 and they also expect prices to rise further but with downward pressure in 2005. These provide a firm underpinning for exploration and suggest an improved outlook for exploration.

As reported above, both world and domestic mineral exploration levels in 2002–03 have arrested a falling trend in recent years. In addition, this year has seen only limited mergers and acquisitions of mining companies compared with the past few years. The higher metal prices, particularly for the base metals and the sustained higher gold price levels are conducive to greater exploration activity in 2004. Coupled with the improved price outlook, the anticipated growth in demand for commodities, especially from China, provides a sound fundamental footing for exploration to grow in the short to medium term, which will be strengthened given implementation of recommendations from the Minerals Exploration Action Agenda.

Offshore Mineral Exploration in Commonwealth Waters

The Commonwealth *Offshore Minerals Act 1994* provides the statutory framework for the exploration for, and the production of minerals, other than petroleum on Australia's continental shelf three nautical miles beyond the territorial baseline of the States and Territories. The administration is shared between the Commonwealth and the States and the Northern Territory. The Joint Authority consists of the relevant Commonwealth minister and State/NT minister and is responsible for major decisions relating to titles, such as grants, refusals, etc. The State/NT minister is called the Designated Authority and is responsible for the normal day-to-day administration of the Commonwealth legislation. Applications for a mineral exploration licence (MEL) are made to the Designated Authority.

Appendix 1

Abbreviations and Acronyms

ABARE Australian Bureau of Agricultural and Resource Economics	Mlbs million pounds
ABS Australian Bureau of Statistics	mm millimetre
AEDR accessible economic demonstrated resources	Moz million ounces
AIMR Australia's Identified Mineral Resources	Mt million tonnes
BRS Bureau of Resource Sciences	Mtpa million tonnes per annum
c carat	MW megawatt
cpt carats per tonne	na not available
CSIRO Commonwealth Scientific and Industrial Research Organisation	NSW New South Wales
EAR-1 estimated additional resources – category 1	NT Northern Territory
EDR economic demonstrated resources	OECD/NEA Organisation for Economic Cooperation and Development/Nuclear Energy Agency
GIS geographical information system	oz ounces
g grams	PDR paramarginal demonstrated resources
g/t grams per tonne	PGM platinum-group metals
GL gigalitre	ppm parts per million
Gt gigatonne	Qld Queensland
IAEA International Atomic Energy Agency	RAB rotary air blast
JORC Joint Ore Reserve Committee – <i>Australasian Code for Reporting of Identified Mineral Resources and Ore Reserves</i>	RAR reasonably assured resources
kg kilogram	RC reverse circulation
km kilometre	SA South Australia
kt kilotonne (thousand tonnes)	SDR subeconomic demonstrated resources
ktpa kilotonne per annum	t tonne
L litre	Tas. Tasmania
lbs pounds	tpa tonnes per annum
m metre	U uranium
m³ cubic metre	U₃O₈ uranium oxide
Mc million carats	USA United States of America
MEL mineral exploration licence	USGS United States Geological Survey
ML million litres	US\$ United States of America dollar
	Vic. Victoria
	WA Western Australia
	\$1M million dollars

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. It was decided that the term 'reserves' would not be used for regional or national aggregates of resources, so as to avoid the confusion arising from its use with different meanings in other contexts.

The Bureau of Resource Sciences (BRS) was formed in 1992 by combining the Mineral and Petroleum Resource Assessment Branches of the BMR with the Bureau of Rural Resources. 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. AGSO was later renamed to Geoscience Australia and estimates prepared by BRS, AGSO and Geoscience Australia 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 is a report by 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 JORC Code are compatible, and data reported for individual deposits by mining companies are used by Geoscience Australia in the preparation of its assessments of Australia's mineral resources

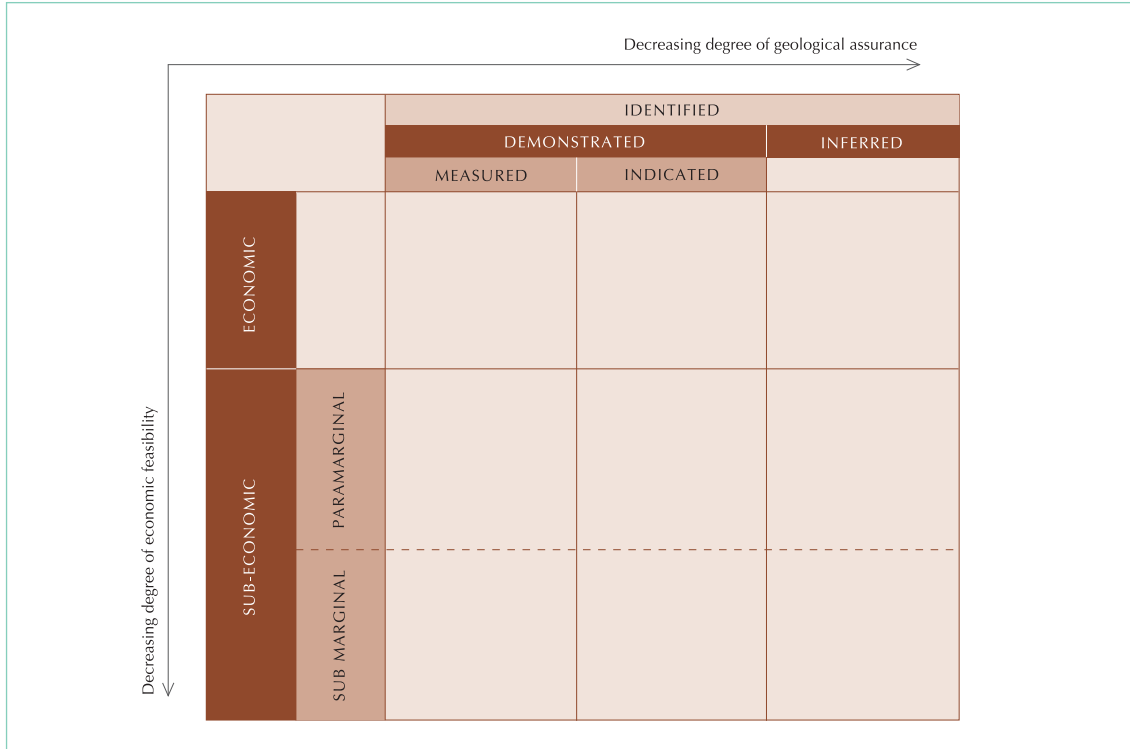
CLASSIFICATION PRINCIPLES

Geoscience Australia 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 (eg. 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 timeframe) feasible (see guideline i).

CATEGORIES OF RESOURCES BASED ON DEGREE OF ASSURANCE OF OCCURRENCE

Identified (Mineral) Resource: 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.

GEOSCIENCE AUSTRALIA 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 (eg. a company's costs and required internal rate of return), and these data may not be available to Geoscience Australia. 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 Geoscience Australia, 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 (ie. 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 resources' is used when allowance has been made for mining as well as processing losses. 'Mineable resources' is used when allowance has been made for mining losses only. For coal, these terms are used differently – the term 'Recoverable coal resources' is used when allowance has been made for mining losses only. 'Saleable coal' is used when allowance has been made for mining as well as 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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