



Australian Government  
Geoscience Australia

# AUSTRALIA'S IDENTIFIED MINERAL RESOURCES 2007



**Australian Government**  
**Geoscience Australia**

Industry, Tourism and Resources Portfolio

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

Parliamentary Secretary: The Hon. Bob Baldwin, MP

**Geoscience Australia\***

Chief Executive Officer: Dr Neil Williams

© Commonwealth of Australia, 2007

This work is copyright. Apart from any fair dealings for the purposes of study, research, criticism, or review, as permitted under the Copyright Act 1968, no part may be reproduced by any process without written permission. Copyright is the responsibility of the Chief Executive Officer, Geoscience Australia. Requests and enquiries should be directed to the Chief Executive Officer, Geoscience Australia, GPO Box 378, Canberra ACT 2601.

ABN: 80 091 799 039

Geoscience Australia has tried to make the information in this product as accurate as possible. However, it does not guarantee that the information is totally accurate or complete. Therefore, you should not rely solely on this information when making a commercial decision.

ISSN 1327-1466

***Bibliographic reference: Geoscience Australia 2007. Australia's Identified Mineral Resources 2007. Geoscience Australia, Canberra.***

**FRONT COVER:** Nelson Point iron ore port facilities, Western Australia (BHP Billiton Ltd)

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

## Foreword

Geoscience Australia provides important information on Australia'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, which takes a long term view of what is potentially economic. Data on mining company estimates of ore reserves (JORC Code), which are generally based on short- to medium-term commercial considerations, are included for comparison. The assessment also 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 Australian 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 levels of exploration activity.

Australia's resource stocks remain healthy overall, although there has been a levelling off of resource trends for several major commodities, eg. nickel and copper. Reflecting strong world demand for mineral resources, expansions in mine production of thermal coal, iron ore and other commodities continued in 2006 and the mineral resources sector overall contributed substantively to Australia's prosperity – economically, environmentally and socially. The 'minerals boom' in the Australian economy continued during 2006. Australian Bureau of Agricultural and Resource Economics reported that in 2006–07, the value of Australia's exports of mineral and energy commodities (excluding petroleum and gas) was \$90.8 billion which represented about 42% of the value of total exports of goods and services from Australia.

The ability of Australia's minerals sector to sustain its strong recent growth remains dependent on effective exploration, leading to discovery and development of new ore deposits. Successful exploration outcomes rely heavily upon continuing updates of pre-competitive geoscience data by government agencies. In particular, there is a need for state-of-the-art geoscientific synthesis and integrated research to reduce risks in identifying exploration targets in prospective frontier regions.

In 2006–07, Geoscience Australia embarked on a major program, extending over five years, to better understand the geological potential of onshore Australia for both minerals and petroleum. The research will apply the latest developments in geophysical imaging and mapping technologies, including seismic, airborne electromagnetics and radiometrics. These will assist in defining the potential for new mineral energy sources and also highlight the potential for geothermal energy from heat producing terrains under blankets of sedimentary cover.

*Australia's Identified Mineral Resources* provides fundamental data in support of this work and industry exploration programs. Much of the data can be accessed in a spatial context through the online *Atlas of Australia's Mineral Resources, Mines and Processing Centres*. The atlas, at [www.australianminesatlas.gov.au](http://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  
Geoscience Australia





# Contents

Foreword . . . . .	i
Summary . . . . .	1
Introduction . . . . .	2
Trends in Australia's Economic Demonstrated Resources of major mineral commodities . . . . .	5

## COMMODITY REVIEWS

Bauxite . . . . .	12
Black coal . . . . .	13
Brown coal . . . . .	21
Coal bed methane . . . . .	23
Copper. . . . .	24
Diamond . . . . .	28
Gold . . . . .	29
Iron ore . . . . .	36
Lithium. . . . .	44
Magnesite. . . . .	44
Manganese ore. . . . .	46
Mineral sands. . . . .	48
Molybdenum . . . . .	52
Nickel . . . . .	53
Niobium. . . . .	58
Phosphate . . . . .	58
Shale oil. . . . .	60
Tantalum . . . . .	61
Thorium. . . . .	62
Tin. . . . .	64
Tungsten . . . . .	66
Uranium. . . . .	67
Vanadium. . . . .	73
Zinc, lead, silver. . . . .	74

## PRODUCTION AND RESOURCE LIFE

Production and resource life. . . . .	80
---------------------------------------	----

## EXPLORATION

Exploration. . . . .	84
Exploration outcomes. . . . .	86
Outlook for exploration . . . . .	87
Exploration stage . . . . .	87
Exploration drilling. . . . .	87
World exploration. . . . .	87
Offshore mineral exploration in Commonwealth waters. . . . .	88

## APPENDICES

Appendix 1: Abbreviations and acronyms . . . . .	89
Appendix 2: National classification system for identified mineral resources. . . . .	90
Appendix 3: Staff – Resources and Advice, Minerals Exploration Promotion Projects . . . . .	95

## TABLES

- Table 1:** Australia's resources of major minerals and world figures as at December 2006
- Table 2:** Australian gold production 2002 to 2006
- Table 3:** Estimated thorium resources by country
- Table 4:** Correlation of resource classification schemes for uranium
- Table 5:** Uranium resources in States and Northern Territory at December 2006
- Table 6:** Australian production and exports of selected mineral products 2006
- Table 7:** Years of Accessible Economic Demonstrated Resources (AEDR) at the production levels for the year (rounded to nearest 5 years)
- Table 8:** Australian mineral exploration expenditure by commodity, 2005 and 2006 (Source: ABS)
- Table 9:** Australian mineral exploration expenditure by State, 2005 and 2006 (Source: ABS)

## FIGURES

- Figure 1:** Trends in Economic Demonstrated Resources (EDR) for major commodities since 1975
- Figure 2:** Australian mineral exploration expenditures by commodity in constant 2005–06 dollars (Based on ABS data deflated by Consumer Price Index series).
- Figure 3:** Australian mineral exploration expenditures, excluding gold and base metals, in constant 2005–06 dollars (Based on ABS data deflated by Consumer Price Index series).
- Figure 4:** Australian mineral exploration spending by commodity (Source: ABS)
- Figure 5:** Australian mineral exploration spending by State (Source: ABS)
- Figure 6:** Distribution of world non-ferrous mineral exploration budgets, 2006 (Source: Metals Economics Group)

## PHOTOGRAPHS

- Photo 1:** Nelson Point iron ore port facilities, Western Australia (BHP Billiton Ltd)
- Photo 2:** Loading manganese ore at Groote Eylandt, Northern Territory (Groote Eylandt Mining Company)
- Photo 3:** Loading coal at the Poitrel mine, Queensland (BHP Billiton Mitsubishi Alliance)
- Photo 4:** Isaac Plains coal handling and preparation plant, Queensland (Aquila Resources Ltd)
- Photo 5:** Kalgoorlie Super Pit, Western Australia (Kalgoorlie Consolidated Gold Mines Ltd)
- Photo 6:** The Koolan Island iron ore mine, Western Australia (Mount Gibson Iron Ltd)
- Photo 7:** Loading iron ore at the Port of Geraldton, Western Australia (Midwest Corporation Ltd)
- Photo 8:** Bootu Creek manganese ore mine, Northern Territory (OM Holdings Ltd)
- Photo 9:** Concentration plant at Collingwood tin mine, Queensland (MetalsX Ltd)
- Photo 10:** Hydrated uranium oxide ('yellowcake') in 200 litre drums ready for shipment, Beverley in-situ leach uranium operation, South Australia (Heathgate Resources Ltd)
- Photo 11:** Dragline removing overburden at the Blackwater Mine, Queensland (BHP Billiton Mitsubishi Alliance)
- Photo 12:** Iron ore exploration at Mount Weld, Western Australia (Midwest Corporation Ltd)

## Summary

Australia's economic demonstrated resources (EDR) of the following mineral commodities increased during 2006 – black coal, copper, gold, iron ore, rutile, zircon, platinum group metals, silver, tin, tungsten and vanadium. EDR of bauxite, cobalt, diamond (gem and industrial), lead, manganese, nickel, uranium and zinc decreased in the same period. EDR for brown coal, magnesite, molybdenum, niobium, shale oil and tantalum remained at levels similar to those reported in 2005. Estimates of Australia's resources of coal bed methane gas are reported for the first time in AIMR.

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. Sustained increases in prices for most metal and mineral commodities over recent years has allowed companies re-assess the economic viability of lower grade resources and deposits which were previously considered to be uneconomic. Overall this has contributed to an increase in EDR for many metal and mineral commodities.

**World ranking:** Australia's EDR of mineral sands (rutile and zircon), nickel, tantalum, uranium, thorium, zinc and lead remain the world's largest, while bauxite, black coal, brown coal, copper, gold, iron ore, ilmenite, 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 inaccessible for mining because of government policies or environmental and land access 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. AEDR of most major commodities can sustain current rates of mine production for many decades. While this is the longer term assessment, resource life based on ore reserves is shorter in duration reflecting a shorter term commercial outlook.

Based on AEDR, the resource lives for gold (an average of 22 years at current rates of production), lead (just over 30 years), zinc (around 30 years) and diamonds (about 7 years) are the lowest. These assessments continue to highlight the need for ongoing successful exploration in the short and medium terms to sustain production of these commodities at current levels.

**Mineral exploration:** Australian mineral exploration spending in 2006 rose by 29% to a record \$1463.9 million. This growth reflects strong growth in prices for many commodities on the back of anticipated strong and growing demand, particularly from China.

While gold remained the predominant target in calendar year 2006 its share of total spending fell again to 29%. Gold exploration spending totalled \$429.8 million in the year, an increase of almost \$45 million. The base metal group had a substantial increase in its share of total spending to 29% with actual spending rising by \$105.7 million to \$426.1 million. The growth in base metals was driven by substantial increases in zinc-lead-silver exploration which more than doubled to \$100.7 million and copper which rose by 68% to \$177.5 million. A fall in the level of exploration for nickel-cobalt in 2006 prevented the base metals group from being the major exploration target. Spending on nickel exploration fell by \$20.2 million to \$147.9 million. Uranium exploration spending also more than doubled in 2006 rising from \$37.7 million to \$80.7 million. Iron ore exploration rose by \$72.5 million to \$224.7 million and its share of total spending increased to 15.3% in response to continuing strong international demand, particularly from China. Similarly coal exploration grew strongly rising from \$145.6 million to \$198.7 million in the year.

The increase in exploration activity saw strong growth in the number of reported intersections of mineralisation and several new discoveries. Indicative of the more significant announcements during the year were about Gullivers and Cooljarloo North (mineral sands), Saxon (nickel), Tekapo (gold-copper), Tandarra (gold), Cuttaburra (base metals), Swan (copper-gold-uranium), Rocklands (copper) and Tropicana (gold). Ongoing exploration also resulted in increases in resources in many known deposits.

Responding to world demand there was substantial activity in the iron ore sector with new resources and drilling results released for many smaller deposits and prospects. Similarly uranium exploration surged and the number of new companies with a focus on uranium is likely to ensure spending continues to grow.

## 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 (ABS) and provide input into Australian Government policy decisions relating to the minerals sector, sustainable development of resources and financial allocations. Other Australian Government departments and agencies that utilised the data in this context during 2006 included the Department of Industry, Tourism and Resources, Department of the Environment and Heritage, the Department of Prime Minister and Cabinet, and the Commonwealth Grants Commission.

*Australia's Identified Mineral Resources 2007* presents estimates of Australia's mineral resources of all major and several minor mineral commodities (Table 1), based on published and unpublished data available to Geoscience Australia up to the end of December 2006. 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 2007* provides information and analysis on mineral exploration expenditures in Australia for 2005–06 and calendar year 2006. Trends in expenditure since 1970 and the early 1990s are presented and discussed.

## National Resource Classification Scheme

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, 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 Exploration Results, Mineral Resources and Ore Reserves* (known as the JORC Code) used by industry for reporting ore reserves and mineral resources.

Economic Demonstrated Resources (EDR) are defined as the sum of measured and/or indicated resources (as defined in Appendix 2), which at the time of determination, profitable extraction or production under defined investment assumptions has been established, analytically demonstrated, or assumed with reasonable certainty (refer Guideline (iii) in Appendix 2). 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. 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 noted.

## Accessible Resources

Geoscience Australia also assesses 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-access restrictions that prevent mining such as: location within National/State parks and conservation zones or military training areas, environmental protection issues and absence of permission from traditional owners. Accessible economic demonstrated resources (AEDR), as shown in Table 1, represent the resources within the EDR category 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.



Table 1. Australia's resources of major minerals and world figures as at 31 December 2006.

Commodity	Units	Australia							World	
		Demonstrated Resources			Inferred Resources (a)	Accessible EDR (AEDR)(b)	JORC Reserves(c) (% of AEDR)	Mine Pro- duction(d) 2006	Economic Demon- strated Resources(e)	Mine Pro- duction(f) 2006
		Economic (EDR)	Subeconomic							
			Para- marginal	Sub- marginal						
Antimony	kt Sb	93	31	53	52	93	58 (62%)	–	1800	117
Asbestos										
Chrysotile ore	kt	–	46.2	–	75	–	–	–	large	2.3(g)
Crocidolite fibre	kt	–	0.4	–	2	–	–	–	large	
Bauxite	Gt	5.7	0.7	1.4	1.1	5.4	1.8 (33%)	0.062	25	0.169(e)
Black coal in situ recoverable	Gt Gt	57.3 39.6	3.7 2	10.7 7.2	94.2 58.9	39.5	12.1(h) (31%)	0.404(i)	734(j)	5.1(j)(k)
Brown coal in situ recoverable	Gt Gt	41.5 37.3	43.4 39	18.1 16.3	112 100.8	29.8	4.9(h) (16%)	0.067(j)	155(j)	0.85(j)
Cadmium	kt Cd	62.9	9.6	18.6	1	62.9	53 (84%)	0.46	583	18
Cobalt	kt Co	1399	239	104	1523	1399	469 (34%)	5.05	7000	57
Copper	Mt Cu	42.4	6.4	1.1	34.8	42.4	18.1 (43%)	0.875	498	15.3
Diamond gem & near gem industrial	Mc Mc	109.9 114.3	96.8 100.7	0.2 0.3	12.9 13.4	109.9 114.3	108.4 (99%) 112.8 (99%)	14.4 14.9	– 600	101 75
Fluorine	Mt F	–	0.2	23.7	21.3	–	–	–	112(l)	2.4
Gold	t Au	5480	1265	128	4499	5420	3329 (61%)	246	42 480	2500
Iron ore	Gt	18.6	0.2	1.8	17.9	18.5	7.8 (42%)	0.275	163	1.7
Lead	Mt Pb	23.5	7.9	2.6	19.6	23.5	10.6 (45%)	0.668	75	3.36
Lithium	kt Li	170	54	26	7	170	145 (85%)	(m)	4100	21.3(n)
Magnesite	Mt MgCO <sub>3</sub>	344	22	35	931	344	37.5 (11%)	0.447	7630	14.05(n)
Manganese ore	Mt	139	23	167	160	139	112 (80%)	4.6	1200	31
Mineral sands										
Ilmenite	Mt	218.5	48.8	0.1	126	182	41.3 (23%)	2.4	1124	9.47
Rutile	Mt	21.7	13.7	0.14	28	16	4.19 (26%)	0.232	55	0.51(n)
Zircon	Mt	33.9	19.9	0.15	30	25.7	5.3 (21%)	0.49	78	0.93
Molybdenum	kt Mo	0.4	282.5	3.7	441	0.4	0 (–)	–	8600	179
Nickel	Mt Ni	23.7	2.3	1.2	22.2	23.7	7 (29%)	0.185	63.8	1.5
Niobium	kt Nb	194	129	0	389	194	21 (11%)	(o)	4400	59.9
Phosphate rock	Mt	85*	980*	–	1085*	85*	85* (100%)	2.145	18 000	145
PGM (Pt, Pd, Os, Ir, Ru, Rh)	t metal	19.9	119	39.3	135	15.6	0.7 (4%)	0.72	71 000	445(p)
Rare earths (REO & Y <sub>2</sub> O <sub>3</sub> )	Mt	0.5	2	12.2	12	0.1	0 (–)	–	89	0.1
Shale oil	GL	4.6	202	3719	41 425	4.6	4.6 (100%)	0	612 363(q)	0.668(r)
Silver	kt Ag	45.6	19.8	7.7	34.1	45.6	26.4 (58%)	1.727	285	19.5
Tantalum	kt Ta	52	32	0.2	69	52	40.3 (78%)	0.58(s)	55	1.14
Tin	kt Sn	247	48	128	309	247	137 (56%)	1.478	6100	273
Thorium	kt Th	–	46.3(t)	–	406	–	–	–	–	–
Tungsten	kt W	72.1	10	27.5	48	72.1	68.1 (94%)	0	2900	73.3
Uranium	kt U	714	12	0	518	562	342 (61%)	7.584	2643(u)	39.35(v)
Vanadium	kt V	832	213	1710	3051	0	0 (–)	0	13 000	62.4
Zinc	Mt Zn	40.6	17.1	2.5	27.2	40.6	21.7 (54%)	1.362	228	10

## Resource Life

The national total ore reserves (OR) figures shown in Table 1 are from estimates prepared by companies for mine planning and marketing purposes; they generally have a shorter term outlook than EDR. 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 of resource life 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.

### Notes for Table 1

**Abbreviations:** t = tonne; m<sup>3</sup> = cubic metre; L = litre; kt = 10<sup>3</sup>t; Mc = 10<sup>6</sup> carat; Mt = 10<sup>6</sup>t; Gt = 10<sup>9</sup>t; GL = 10<sup>9</sup>L.

- 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).
- e) Sources: Geoscience Australia for Australian figures, USGS Mineral Commodities Summaries for other countries.
- f) World mine production for 2006, 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) 222 101 t of spodumene concentrate (Sons of Gwalia Ltd).
- n) Excludes USA.
- o) Not reported by mining companies.
- p) Latest production figure is 358 t for 2003 from USGS Mineral Commodities Summaries 2004.
- q) Source: WEC Survey of Energy Resources 2004.
- r) Latest production figures for end 2002 from WEC Survey of Energy Resources 2004.
- s) Tantalum production from company data.
- t) Paramarginal resources 29.2 kt from Nolan's Bore and 17.1 kt from Toongi, inferred resources include 24.1 kt from Nolan's Bore and 17.9 kt from Toongi.
- u) Source: OECD/NEA & IAEA (2006). Compiled from the most recent data for resources recoverable at <US\$80/kg U.
- v) Source: Ux Weekly, March 26 2007.
- \* Denotes a commodity for which last year's figures are reported (i.e. as at 31-Dec-2005). Otherwise, figures are as at 31-Dec-2006.

Commodity	Units	Australia			
		Demonstrated Resources			Inferred Resources (a)
		Economic (EDR)	Subeconomic		
			Sub-marginal	Para-marginal	
Copper	Mt Cu	58.8	6.6	1	38.5
Uranium	kt U	953	11		593

Since the compilation of resource estimates for Dec 2006, BHPBilliton have released revised estimates of reserves/resources for the Olympic Dam deposit, Quasar Resources/Alliance Resources JV released the first estimates of uranium resources for the 4 Mile deposit and ERA released updated estimates for the Ranger 3 orebody. Revised estimates of Australia's total resources of copper and uranium are shown here as at August 2007. These include the large increases in resources for these deposits.

## 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 1975–2006 (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 the 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 major commodities like black coal, and base metals have plateaued.

### Black Coal

A major re-assessment of New South Wales 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

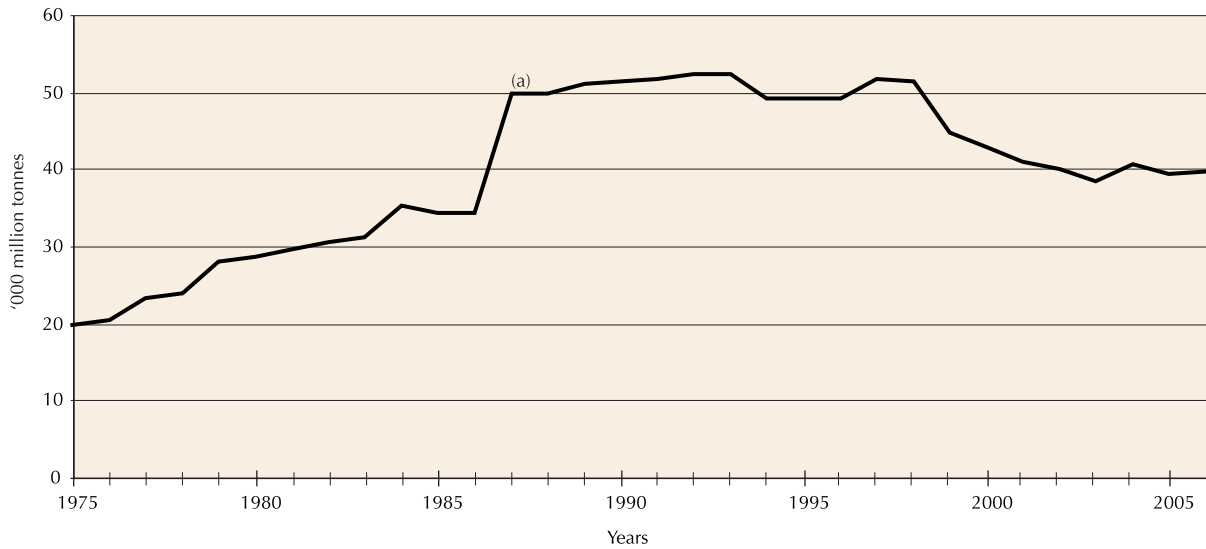
Increases in bauxite EDR in 1989 resulted from delineation of additional resources in deposits on Cape York Peninsula ('b' on Fig. 1). Decreases in bauxite EDR in 1992 were due to re-classification of some resources within deposits on Cape York Peninsula so as to comply with requirements for the JORC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

### Iron Ore

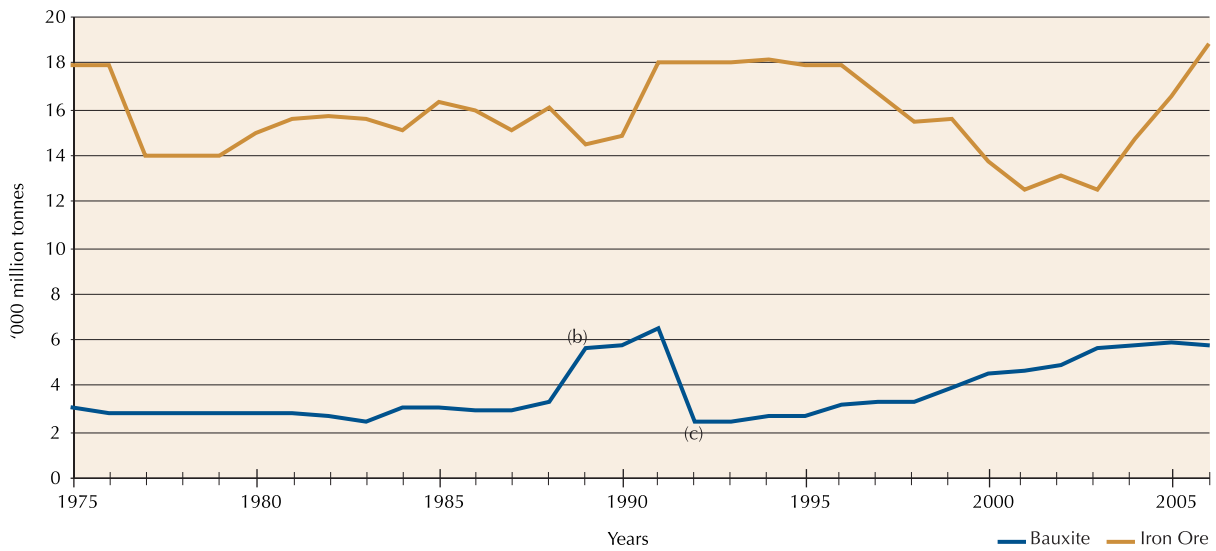
EDR for iron ore declined from 1996 to 2001 due to the combined impacts of mining companies re-estimating ore reserves and mineral resources more conservatively so as to comply with requirements of the JORC Code, and increased rates of mine production. However since 2003 EDR has increased due to reclassification of magnetite resources to economic, newly reported resources and increases in resources at some major mines.

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

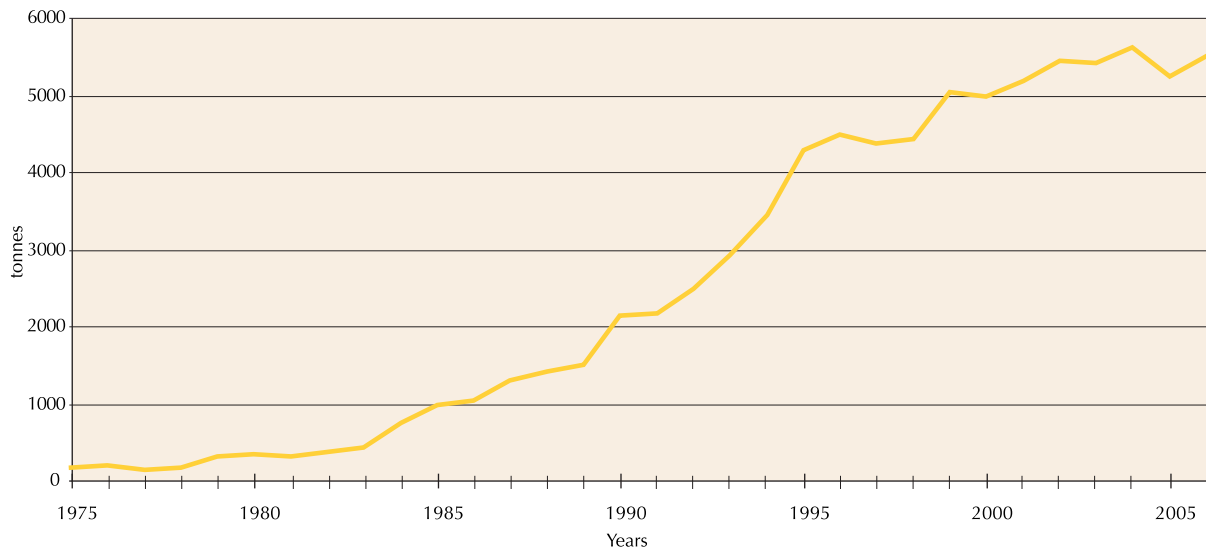
**Black Coal (recoverable)**



**Bauxite, Iron Ore**

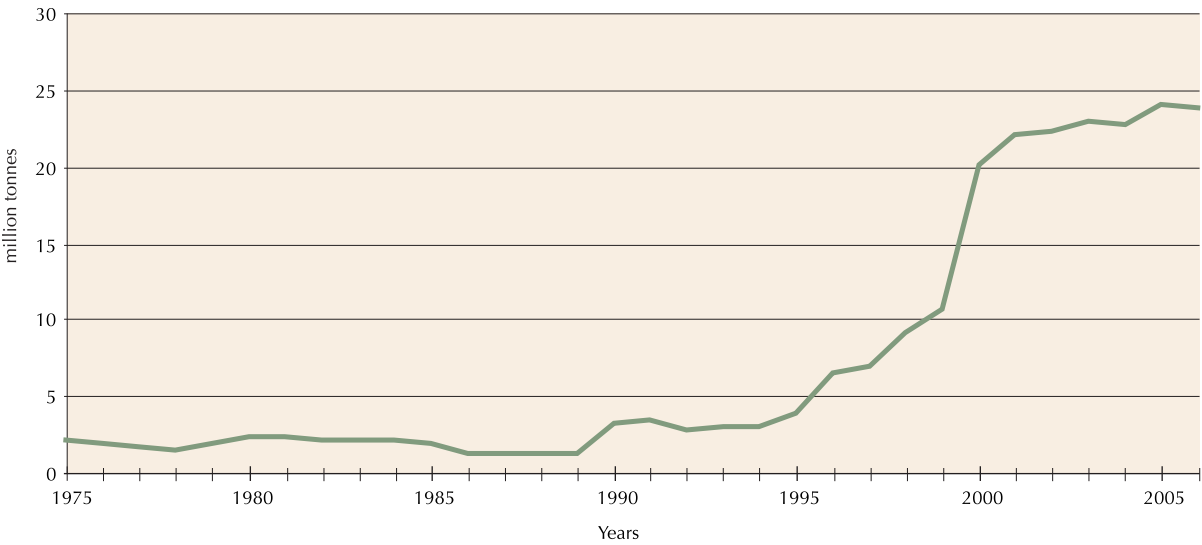


**Gold**

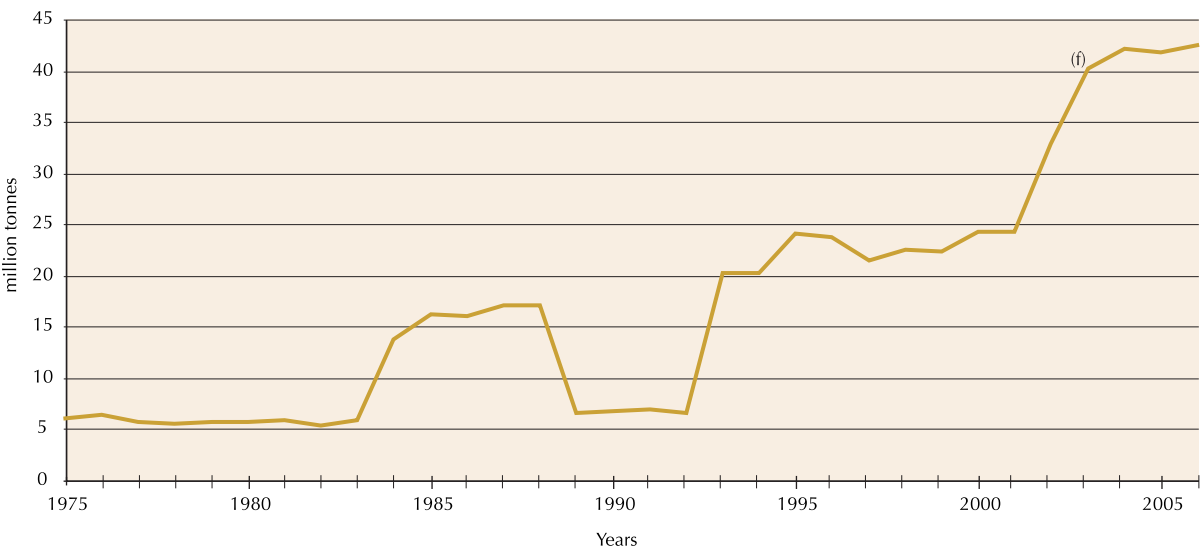




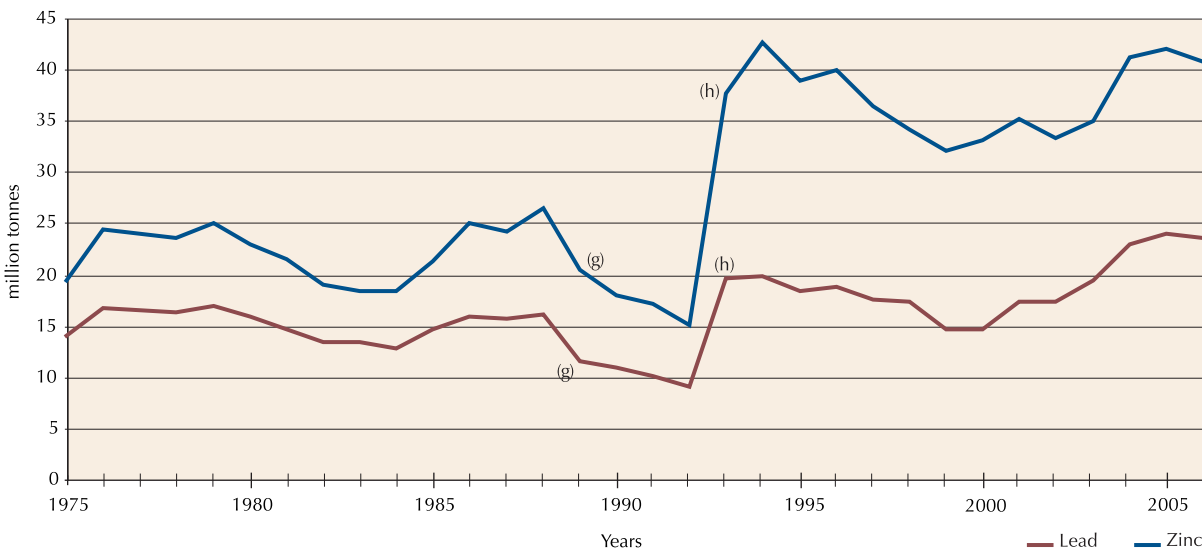
Nickel



Copper

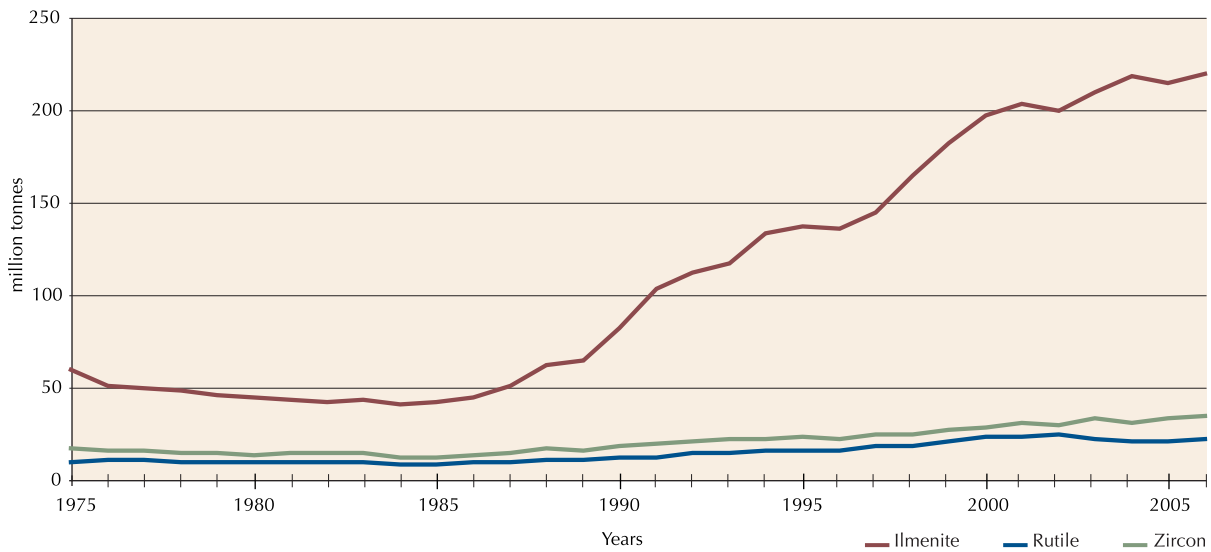


Lead, Zinc

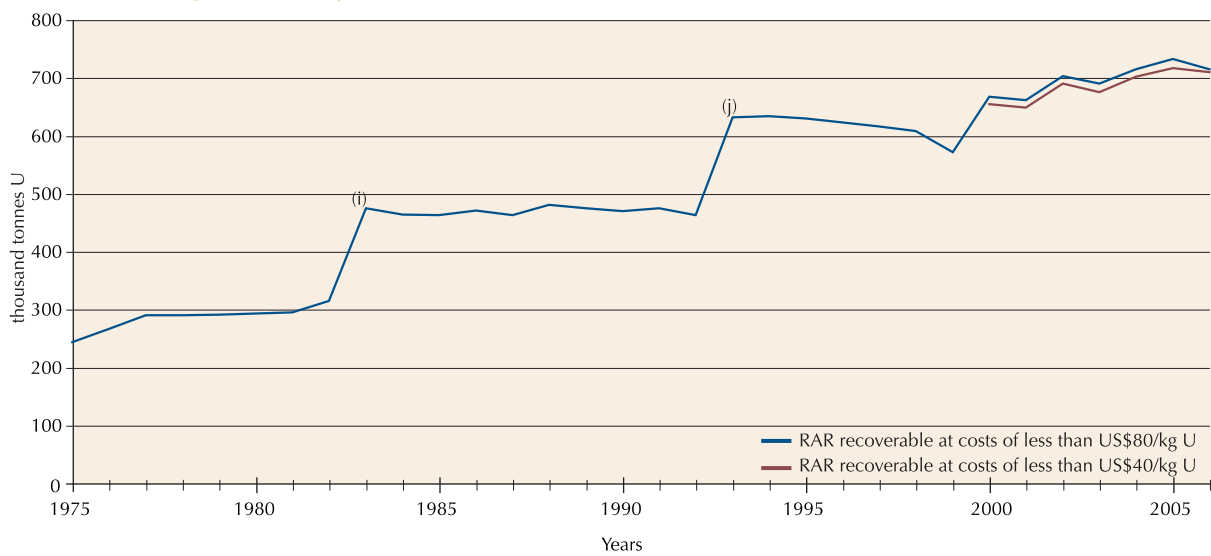


**FIGURE 1: Trends in Economic Demonstrated Resources (EDR) for major commodities since 1975 (continued).**

### 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 for many years. 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.

In recent years, EDR has remained at about the same level because increases in resources for some deposits have been offset by companies reclassifying their lateritic nickel resources to lower resource categories pending more detailed drilling and resource 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 demonstrated 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), New South Wales (Gingko and Snapper) and South Australia (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 Western Australia.

## 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 six deposits have been discovered – of these, only two deposits (Kintyre in the Paterson Province, WA and Junnagunna, north west Qld) have Reasonably Assured Resources recoverable at less than US\$80/kg U (equates with EDR). Hence, the progressive increases in Australia's EDR for uranium from 1975 to the present (as shown in Fig. 1) were largely 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



Loading manganese ore at Groote Eylandt, Northern Territory (Groote Eylandt Mining Company)

## Bauxite

Bauxite is a heterogeneous naturally occurring material from which alumina ( $\text{Al}_2\text{O}_3$ ) 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 diaspor, which has the same composition as boehmite but is denser and harder. Australia is the world's largest producer of bauxite.

The Weipa (Qld) and Gove (NT) bauxite mines have close to 50% available alumina and are amongst the world's highest grade deposits. The Western Australian deposits in the Darling Range and the undeveloped Mitchell Plateau are relatively low grade, at around 30% available alumina.

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 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 ( $\text{NaAlF}_6$ ).

Australia's aluminium industry is a highly integrated sector of mining, refining, smelting and semi-fabrication centres and of major economic importance nationally and globally. 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. The industry is geared to serve world demand for alumina and aluminium with over 80% of production being exported. Figures on the value of industry exports are collated half-yearly by the ABS and the Australian Aluminium Council compiles data on bauxite, alumina and aluminium exports, which it updates on a monthly basis.

### Resources

Vast resources of bauxite, located in the Weipa and Gove regions adjacent to the Gulf of Carpentaria and in the Darling Range south of Perth, underpin the long-term future of Australia's aluminium 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 5.7 Gt in 2006 was relatively unchanged from the previous year, the net effect of exploration drilling adding to mineral resources and offsetting depletion through production. Movement in subeconomic and inferred resources was also static.

### Accessible EDR

Less than 5% of bauxite EDR is inaccessible for mining. This represents 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 shows the resource life for existing bauxite operations is on average around 70 to 75 years. The potential of unexplored regions, however, is likely to extend resource life well beyond this.

### JORC Reserves

Approximately 30% of AEDR comprises JORC Code ore reserves as reported by industry. The remaining represents resources assessed by Geoscience Australia as being economically recoverable from *measured* and *indicated* categories of *mineral resources*, as defined under the Code and other classification systems used by companies not listed on the Australian Stock Exchange. The surface expression of bauxite and confidence in lateral continuity of thickness and grade make it possible in certain terrains to classify some *inferred resources* as EDR.

### Exploration

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

## Production

Globally in 2006, Australia was the leading producer of bauxite and alumina, and the fifth largest aluminium producer. Production totalled 61.8 Mt of bauxite (36% of world production), 18.3 Mt of alumina (28%) and 1.9 Mt of aluminium (5.8%).

Production of bauxite at Weipa in 2006 was a record 16.1 Mt, 4% higher than in 2005. This increase was a result of the ongoing ramp up of the NE Weipa project, which delivered increased production from both the East Weipa and Andoom mines.

## World Resources

Based on USGS data for other countries, Australia's demonstrated bauxite resources of 7.8 Gt rank second in the world after Guinea and ahead of Brazil, Jamaica and China.

## Industry Developments

The 2006 Sustainability Report on Australia's bauxite, alumina and aluminium industries was released by Australian Aluminium Council in mid-2007. The report, the third in a series, documents how the industries are using physical resources, the impacts of that use and how they are managing outputs and working to reduce the impact of production processes.

Companies engaged in Australia's bauxite-alumina-aluminium industry continued to respond to the needs of increased trade during 2006. At Weipa a second shiploader was commissioned to ensure reliability of bauxite supply to customers and Rio Tinto Marine committed to purchasing three bulk ore carriers to be used primarily for shipments from Weipa to Gladstone.

## Black Coal

Coal is a combustible sedimentary organic rock which is mainly composed of carbon, hydrogen and oxygen. Black coal has a higher rank, is harder, has a lower moisture content and produces more energy than the lower ranked brown coal. Australia's deposits of black coal occur in all States and the Northern Territory and range in age from 140 to 225 million years old. Black coals are used mainly as a fuel in power stations, in steelmaking and cement manufacturing. Black coal also is used in alumina refineries, paper manufacturing, food processing and chemical manufacturing, for products such as pitch, creosote oil and naphthalene.

At December 2005 there were 107 operating black coal mines in Australia with the bulk of mines in New South Wales (58) and Queensland (43). Locally significant mines operate at Collie (WA), Leigh Creek (SA) and in the Fingal Valley (Tas).

## Resources

In-situ EDR for 2006 increased 2.7% to 57.3 Gt and recoverable EDR increased 1.0% to 39.6 Gt. The increase was due mainly to a reclassification of resources in the Illawarra Coalfield and increases in resources at mines such as New Acland, Newlands, Wards Well, Moorvale, Mt Arthur, and Moolarben. This was partially offset by decreased resources at Red Hill, Wallarah No. 2 and Elimatta. Queensland (53%) and New South Wales (42%) had the largest share of recoverable EDR in Australia.

The in-situ paramarginal demonstrated resources decreased 26.6% to 3.7 Gt and recoverable paramarginal demonstrated resources decreased 24.3% to 2.0 Gt due almost entirely to the reclassification of resources in the Illawarra Coalfield. In-situ subeconomic demonstrated resources decreased by 13.6% to 10.7 Gt and recoverable subeconomic demonstrated resources decreased 12.0% to 7.2 Gt mainly due to decreases at Ulan and Wallarah No. 2. In-situ and recoverable inferred resources increased 3.6% to 94.2 Gt and 3.4% to 58.9 Gt respectively. Large increases in inferred resources occurred at Cook, Lancewood, Saraji East, South Blackwater, Taabinga and Bylong. New South Wales has 56% of the recoverable inferred resources followed by South Australia with 24%.



## Accessible EDR

Almost all black coal EDR is accessible with only a relatively small tonnage at Hill River (WA) being quarantined within State Reserves. The resource life of the accessible EDR of 39.5 Gt was about 100 years at current rates of production.

## JORC Reserves

JORC Code reserves are 12.1 Gt or 31% of accessible EDR. Included in the 12.1 Gt are Geoscience Australia's estimate of reserves at some operating mines which had no reported JORC Code reserves. This constituted 2.5 Gt or about 20% of JORC Code reserves. BHP Billiton, Rio Tinto, Xstrata Coal and Anglo Coal manage about 61% of JORC reserves in Australia. The resource life of the JORC Code reserves of 12.1 Gt is 30 years.

## Exploration

Data published by ABS on coal has indicated that exploration expenditure for 2006 totalled \$198.7 million, up from \$145.6 million in 2005. Expenditure in Queensland was \$110.6 million or 56% of the total and \$68.2 million in New South Wales or 34% of the total. Exploration also occurred in South Australia, Western Australia and Victoria.

## Production

In 2006 Australia produced 404 Mt of raw coal (398 Mt in 2005) which yielded 302 Mt of saleable coal (303 Mt in 2005). Exports of black coal during 2006 were 124 Mt of coking coal valued at \$16 billion and 112 Mt of steaming coal valued at \$7 billion. ABARE has projected that Australia's saleable production will grow to 378 Mt by 2011–12. Exports of coking and thermal coals are projected to rise to 156 Mt and 148 Mt respectively by 2011–12.

## World Ranking

Australia has 5% of the world's recoverable black coal EDR and ranks sixth behind USA (29%), Russia (20%), China (12%), India (12%) and South Africa (7%).

Australia produced about 6% of the world's black coal in 2006 and ranked fourth after China (45%), USA (19%) and India (8%).

## Industry Developments

### QUEENSLAND

**Rio Tinto Coal Australia:** At Kestrel, planning is progressing to widen the longwall face for the 400 series blocks due to be mined from 2012. A feasibility study is evaluating different longwall configurations for the remaining resources. The US\$223 million expansion at Hail Creek increased production capacity from 6 to 8 Mtpa in August 2006. The expansion duplicated the wash plant capacity to 12 Mtpa for any future mine expansion. Production at Blair Athol is due to end around 2010. The nearby US\$750 million Clermont mine is planned to commence as production at Blair Athol winds down. The mine will produce 12.2 Mtpa of thermal coal from 2010 over a planned 17 year life. A 15 km conveyor will connect the mine to infrastructure at Blair Athol.

**BHP Billiton Mitsubishi Alliance (BMA):** A new \$40 million system is being developed at the Broadmeadow mine to widen the longwall face from 200 to 320 m. The new high capacity system is expected to be commissioned by March 2008. The long term plan is to mine the Lower Goonyella Seam 30 m below the current operation in the Middle Goonyella Seam. During 2006 a Marion 8200 dragline from the USA was reassembled at the Blackwater open-cut joining seven other draglines removing overburden at the 14 Mtpa mine. In 2006 the Last Drop Project at the Peak Downs open-cut mine investigated the feasibility of reducing coal loss by approximately 9% and mine costs by 8%. Mining of longwall panels in the existing Crinum mine is expected to be completed in 2007. A new Eastern Crinum longwall mine is being developed off the nearby Gregory open-cut highwall to maintain production capacity from mid-2007.





Loading coal at the Poitrel mine, Queensland (BHP Billiton Mitsubishi Alliance)

**BHP Mitsui Coal Pty Ltd:** Construction of the \$315 million Poitrel open-cut mine commenced in March 2006. The coking and PCI mine started operations in November 2006 and is expected to be producing 3 Mtpa by late 2009 with plans to mine up to 5 Mtpa over 22 years. Peabody Australia and BHP Mitsui Coal Pty Ltd agreed, via the Red Mountain Joint Venture, to share mine infrastructure for both the Millennium and Poitrel mines. The coal handling and preparation plant was commissioned in late 2006 with a capacity of 6 Mtpa.

**Xstrata Coal:** At the Oaky No. 1 mine, a second longwall commenced in December 2005 to increase output from 4.5 to 6.5 Mtpa. In September 2006 a 13 MW mine methane power plant was commissioned at Oaky Creek. The Oaky Creek open-cut mine ceased operating in December 2006 due to a high cost structure. Xstrata proposes replacing the Oaky Creek production with lower cost coking coal from the Newlands Wollombi No. 2 Project. The mine will produce up to 2.5 Mtpa of run-of-mine coal for more than 15 years. Longwall production commenced at the Newlands Northern mine in early 2006 and replaced production from the Southern mine which ceased in September 2005. At Rolleston a second dragline is under construction to increase capacity from 6 to 8 Mtpa when commissioned in 2007. A third dragline is planned to take capacity to 12 Mtpa.

**Anglo Coal:** At Callide a new P&H4100XPB shovel was commissioned in July 2006. The 54 m<sup>3</sup> bucket will load the 270 t trucks in three passes. Overburden removal began at the \$674 million Lake Lindsay open-cut mine in July 2006. The mine will produce 4 Mtpa over 30 years and will utilise the infrastructure at the German Creek mine via an overland conveyor to be operational in late 2007. A new Bucyrus Erie 8750 dragline is expected to be operational at Lake Lindsay in 2008. The new 5 Mtpa Grasstrees coking coal mine began commissioning the longwall in August 2006 in the relatively low German Creek seam on a 300 m face. At the Dawson Project construction of the upgrade of the coal handling and processing plant from 7 to 13 Mtpa is on schedule to be commissioned in March 2007.

**Macarthur Coal:** The Olive Downs open-cut mine is planned to be developed as a satellite operation located 20 km north of the Moorvale mine. The 1.0 Mtpa coking coal mine will have a 12 year life with first coal production is expected in mid-2007. At Moorvale West an underground longwall mine is planned to produce 3 Mtpa of coking coal from the Lower Leichardt and Vermont



Isaac Plains coal handling and preparation plant, Queensland (Aquila Resources Ltd)

Upper seams. The Moorvale underground is proposed to advance from the final open-cut highwall. The proposed \$1 billion Queensland Coke and Energy project has stalled due to the inability to secure land title for the project. The project was planned to consume 5 Mtpa of coking coal and produce up to 370 MW of electricity.

**Wesfarmers:** The \$360 million Curragh North Project is expected to be completed in March 2007 when the first coal is due to be transported by a 22 km conveyor to the Curragh washplant. The Curragh complex will then have a production capacity of 9 Mtpa and a project life to 2025.

**Felix Resources:** The Minerva open-cut mine located 45 km south of Emerald was commissioned in March 2006 with a capacity of 2.5 Mtpa. The multi-seam mine will produce export quality Pulverised Coal Injection (PCI) and thermal coal for approximately 14 years.

**Peabody Australia:** The first coal was railed from the \$185 million Millennium open-cut project in July 2006. The mine is expected to produce about 1.5 Mtpa of saleable metallurgical coal from the Rangal Coal Measures. The design capacity of 3 Mtpa is expected to be reached in 2009. During 2006 the Wilkie Creek mine coal production capacity was increased from 1.8 to 2.3 Mtpa.

**Ensham Resources:** A \$600 million expansion of the Ensham thermal coal project from 9 to 20 Mtpa includes the 4 Mtpa Ensham Central open-cut mine which is planned to commence in 2007. A second stage high capacity underground longwall mine is currently under investigation for a proposed 2009 start-up. In January 2007 a \$100 million Bucyrus Erie 8750-63 dragline was commissioned with a capacity of 30 million bank cubic metres (or 60% of Ensham's overburden removal capacity).

**American Metals and Coal International (AMCI):** At Carborough Downs, about 20 km east-north-east of Moranbah, mining operations using continuous miners commenced in September 2006. Production is supplemented from the nearby Broadlea North open-cut mine located 12 km to the north. AMCI have approval to mine 1.9 Mtpa of coking, Pulverised Coal Injection (PCI) and thermal coals from the Rangal Coal Measures. AMCI is proposing to increase the rate of mining to 5 Mtpa by the introduction of a longwall. The Isaac Plains project is a 50:50 Joint Venture between Aquila Resources and AMCI. In May 2006, mining commenced at the Isaac Plains mine located near

Moranbah and coal shipments began in November 2006. The mine is expected to produce 2 Mtpa of coking and thermal coals over a mine life of 10 years. A feasibility study is being undertaken to integrate the Isaac Plains South coal deposit with the Isaac Plains mine infrastructure located 15 km to the north.

**Aquila Resources:** At the Belvedere hard coking coal deposit near Moura the Brazilian company Companhia Vale do Rio Doce (CVRD) has an option to acquire an initial 51% interest in the project on completion of a \$15 million "Exploration Study". Initial studies indicate the potential for an underground operation of up to three longwalls producing 12 Mtpa.

**New Hope Corporation:** Construction of the Stage 2 expansion at New Acland commenced in 2006 with production expected to increase from 2.5 to 4 Mtpa starting in April 2007. The increase in production from New Acland will offset the reduction caused by the planned closure of the Jeebropilly mine in February 2007. A Stage 3 expansion will depend on whether the Tarong Power Station takes up a supply option to buy 5.7 Mtpa over 25 years from 2011.

**QCoal:** The \$120 million Sonoma project located about 6 km south of Collinsville is expected to commence production in mid-2007. The open-cut mine will produce 2 Mtpa of coking and thermal coal initially with plans to ramp up to 4 Mtpa as port capacity becomes available at Abbot Point. The Sonoma project was awarded Major Project Facilitation status by the Australian Government in July 2006.

**CSEnergy:** The 2.8 Mtpa open-cut mine near the \$1.1 billion Kogan Creek power station is due to commence operations in early 2007 to provide coal for commissioning purposes. Commercial operation of the 750 MW power station is expected to begin in September 2007.

**Caledon Resources plc:** In June 2006, Xstrata Coal sold a majority stake in the Cook Colliery to Caledon Resources which plans to increase production to 1.5 Mtpa by 2008 with an ultimate target of 2 Mtpa.

**Cockatoo Coal Ltd:** Proposes developing the Wonbindi open-cut mine located about 30 km north of the Moura rail line. The company plans to produce 1 Mtpa of ultra low volatile Pulverised Coal Injection (PCI) and thermal coal for export commencing in 2007.

## NEW SOUTH WALES

**BHP Billiton:** In early 2006 BHP Billiton was awarded a 5 year exploration licence over the Caroona area in the Gunnedah Basin. BHP Billiton plans to invest \$2 billion on capital and infrastructure with first coal production expected in 2014. In February 2006, BHP Billiton applied for approval to construct a \$20 million adit to extract a 250,000 t bulk sample at the proposed Mount Arthur underground mine. The \$300 million mine would increase capacity from the current 15 Mtpa to up to 23 Mtpa by 2009 and employ around 250 people. The \$80 million 300 m wide Douglas longwall will be employed in Area 3 at Appin while development at Douglas is completed. The Douglas mine is expected to commence in Area 7 in 2007, replacing diminishing reserves at the Appin mine.

**Coal and Allied (CA) (75% Rio Tinto):** In 2006, development consents were granted at the Hunter Valley operation, including the Chestnut Extension, the Carrington Extension and the Riverview Pit. At Bengalla, CA is seeking development approval to increase run-of-mine capacity from 8.7 to 10.7 Mtpa. In November 2006, CA commenced a 12 month feasibility study into the development of Mt Pleasant as either integrated with the nearby Bengalla mine, or as a stand alone operation.

**Xstrata Coal:** At Ulan a new 400 m wide longwall commenced operation in September 2006 with a capacity of 5.5 Mtpa. The 405 m wide \$350 million Blakefield longwall at the Bulga mine is planned to start operating in 2009 to replace the existing Beltana longwall which ceases in 2010. At the Liddell open-cut Xstrata is spending \$91 million to replace the coal preparation plant and increase capacity from 4.2 to six 6 Mtpa in 2008. The Mt Owen coal preparation plant will have a third module added to support the \$99 million Glendell operation which will increase capacity from 6.1 to 9.5 Mtpa by 2008. Ravensworth West commenced in 2006 and will deliver 7.3 Mt over the next six years to Macquarie Generation. Cumnock Coal is evaluating mining options on the current lease area beyond the completion of mining, which is expected in late 2008.



**Anglo Coal:** In May 2006 Anglo announced that the Dartbrook underground mine would be placed on care-and-maintenance by the end of 2006 due to ongoing geological difficulties. At the Drayton open-cut mine Anglo is seeking approval to extend the mine life to 2015 and increase production to 7 Mtpa. A detailed feasibility study has been completed for an open-cut mine on the upper seams at the Saddlers Creek deposit. Conceptual studies have been completed for a longwall operation in lower seams.

**Centennial Coal:** In February 2006 the Delta Drift at the Mandalong mine was completed. This drift enables the transport of coal to the Vales Point Power Station through a series of underground conveyors. Centennial plans to cease longwall mining at Newstan by mid-2008 because of underperformance and variable mining conditions. People and equipment will be redeployed to expand production at Mandalong to above 5 Mtpa. The Awaba mine utilises continuous miners in a retreat configuration, mining small panels via pillar quartering. Centennial has shelved plans to mine the Awaba open-cut following consultation with the local community. The Awaba and Mannering underground mines will cease operating in 2008. The Myuna mine will undergo an expansion to more than 2 Mtpa by utilising an additional mining unit and accessing the Wallarah Seam. At Clarence, development consent was granted in January 2006 over the 700 series panels which will provide an additional 20 years of mine life. In mid-2006 the Springvale-Delta Water Transfer Scheme was commissioned to provide surplus mine water to Delta Electricity's cooling towers. The Charbon mine recommenced pillar extraction in May 2006 by utilising a partial extraction system that enabled access to previously unrecoverable coal. In the Hunter Valley, Centennial is seeking development approval for the \$100 million Anvil Hill open-cut mine. The 10.5 Mtpa thermal coal project is expected to commence in 2008 and operate for at least 21 years.

**Peabody Energy** (formerly Excel Coal): The \$77 million 15 km Wambo rail line was completed in April 2006 and truck haulage to Mt Thorley ceased in June. Development of the \$101 million, 3 Mtpa North Wambo longwall continued during 2006 and is expected to commence production in mid-2007. The \$61 million Wambo open-cut expansion from 3.0 to 4.5 Mtpa was completed in mid-2006. In February 2006, construction commenced at the \$123 million Wilpinjong project which will have an installed capacity of 9 Mtpa. The first coal was railed to Macquarie Generation in late 2006 and production of 5 Mt is expected in 2007.

**Gloucester Coal:** Overburden stripping commenced in May 2006 at the Roseville open-cut extension using smaller equipment to more efficiently and cleanly extract the numerous plies of coal. In early 2006, Gloucester undertook a detailed optimisation review of the Duralie open-cut and in July 2006 received consent to expand the Duralie mine. The newly discovered Clareval Seam is expected to significantly increase the life-of-mine operations. The discovery has prompted Gloucester to increase production from 2.0 to 2.8 Mtpa from 2009 at a cost of \$30 million.

**Felix Resources:** The Ashton underground longwall mine is expected to be commissioned in March 2007 with a capacity of more than 2 Mtpa of semi-soft coking coal. Felix is seeking development approval for the \$220 million Moolarben open-cut mine which is planned to commence production in the second half of 2008 at an initial rate of 4 Mtpa. The mine will provide thermal coal to domestic power stations and export markets. Felix is planning a 4 Mtpa underground longwall mine at Moolarben after the open-cut has reached full capacity. By 2010 Felix expect to be producing in excess of 9 Mtpa over a 25 year mine life.

**Resource Pacific Holdings:** Newpac No. 1 Colliery commenced longwall operations in January 2007 with surface infrastructure due to be commissioned by the end of February. The 4 Mtpa mine will produce a semi-soft coking coal for export markets. Four continuous miners and eight shuttle cars worth \$23 million are due to arrive on-site in mid-2007.

**Gujarat NRE:** The NRE Avondale Colliery portal was re-opened in May 2006 with the aim of recommencing production in 2007 in the Wongawilli Seam. Gujarat plans to ramp up production to 1.5 Mtpa by 2010. Gujarat NRE Coke Ltd has guaranteed to take all coal produced from the colliery for coke production in India.



**Yancoal Australia Pty Ltd:** The \$250 million Austar Longwall Top Coal Caving (LTCC) mine commenced in October 2006. The coking coal mine is expected to produce 2 Mt in the first year and 3 Mtpa thereafter for over 20 years. LTCC can be used in seams heights from 4.5 to 12.5 m and some 80 LTCC faces are currently in operation in China.

**Integra Coal Operations Pty Ltd:** The operations of Camberwell Coal and Glennies Creek have been merged to form Integra Coal. The integrated mining site is located 8 km north of Singleton and produces up to 4 Mtpa of a mixture of premium coking, semi-soft and thermal coals for the export market.

**Donaldson Coal Pty Ltd:** Propose to develop the Abel bord and pillar underground mine from the highwall off the existing Donaldson open-cut. The mine is planned to extract up to 4.5 Mtpa for a 21 year period utilising existing surface infrastructure. The Donaldson open-cut has reserves expected to last until 2012.

**Newcastle Coal Company:** The Tasman underground thermal coal mine located 18 km south of Maitland commenced in late 2006. The 1 Mtpa bord and pillar mine uses the Bloomfield coal handling and preparation plant and rail loader. The project has a 12 to 15 year life employing up to 90 people.

**Northern Energy Corporation:** A 2006 scoping study found that a 1 Mtpa open-cut mine is technically feasible at Ashford north of Inverell. The most likely mining method would be terrace mining along strike with a wash plant for hard coking coal production. Product coal would need to be trucked to Moree then railed to Newcastle.

**Idemitsu Boggabri Coal Pty Ltd:** Commenced mining operations at the \$39 million Boggabri open-cut mine in mid-2006. Initially the mine will produce up to 1.5 Mtpa of semi-soft coking and thermal coal with the potential to increase production to up to 5 Mtpa.

**Whitehaven Coal Mining Ltd:** The Tarrawonga (formerly East Boggabri) coal project, 16 km north east of Boggabri, is a joint venture between Whitehaven Coal Mining Ltd (70%) and Idemitsu Boggabri Coal Pty Ltd (30%). Construction of the 2 Mtpa open-cut thermal coal mine commenced in mid-2006 and first coal was produced in late 2006. The proposed 1.5 Mtpa Belmont open-cut mine is due to commence in 2008 following the completion of operations at the Whitehaven mine. The proposed Sunnyside open-cut mine located 15 km west of Gunnedah is planned to produce up to 1 Mtpa of run-of-mine coal from the Hoskisson seam. At the proposed Narrabri North underground mine, Stage 1 requires an initial production of 1.5 Mtpa using continuous miners. Stage 2 includes the production of an additional 4.5 Mtpa using longwall mining.

**Wyong Areas Coal Joint Venture** (Kores Australia 82.25%): Proposes to develop a 4 to 5 Mtpa longwall mine north of Wyong with initial production expected in 2009 and longwall production to commence in 2010. The Wallarah 2 Coal Project is planned to produce export quality thermal coal for more than 40 years.

## WESTERN AUSTRALIA, SOUTH AUSTRALIA AND TASMANIA

In December 2006 Wesfarmers Energy Ltd completed construction of a 50,000 tpa \$8 million char demonstration plant near the Premier mine in Collie. The Western Australian Government committed to set aside \$60 million for the Bunbury Port Development Fund to develop and improve the port and associated infrastructure to assist the long term export of coal. The Aviva Corporation Ltd completed a pre-feasibility study in August 2006 on mining the Central West coal deposit near Eneabba, 270 km north of Perth. In late 2006 Aviva and ERM Power commenced a joint Preliminary Power Study to investigate the feasibility of a \$700 million 400 MW base load power station. A 2 Mtpa open-cut mine using bulldozers to push coal and overburden onto conveyors could supply coal for more than 30 years.

Altona Resources plc completed the first phase of a coal to oil feasibility study on the Arckaringa coal deposits in South Australia. Altona stated that a cogeneration plant producing 15,000 billion barrels of oil per day of petroleum products and 1,000 MW of electricity is being considered. In November

2006, Altona Resources commenced an investigation into supplying Flinders Power with up to 4 Mtpa of coal for 25 years from the Westfield coal deposit. In June 2006, Babcock and Brown Ltd purchased the 3.7 Mtpa Leigh Creek mine as well as the Northern and Playford power stations near Port Augusta for \$317 million.

**Cornwall Coal Company NL:** At the Duncan Colliery in Tasmania a widehead continuous miner will be used to complete development for a shortwall. At Blackwood No4 a box cut was completed to gain entry to the Fenton Seam.

## INFRASTRUCTURE

In Queensland, port expansions currently being undertaken include:

**Abbott Point Coal Terminal:** The \$116 million Stage 2 expansion from 15 to 21 Mtpa started in mid-2006 and is due to be completed in mid-2007. An Environmental Impact Statement has been commissioned for a possible Stage 3 expansion to 50 Mtpa. Stage 3 is dependent on construction of the Northern Missing Rail Link.

**Dalrymple Bay Coal Terminal:** In August 2006 Babcock and Brown Infrastructure commissioned the new \$30 million RL1 reclaimer which increased capacity from 55 to 59 Mtpa. By optimising plant and equipment another 1 Mtpa was provided in October. The \$270 million Phase 1 expansion from 60 to 68 Mtpa is expected to be completed by the end of 2007. The \$640 million Phase 2 and 3 expansions are planned to increase port capacity to 85 Mtpa by the end of 2008.

**Hay Point Coal Terminal:** In 2006 a \$70 million dredging project removed about 9 million cubic metres of material to allow most ships to be fully loaded. The 1.8 m increase in port depth will allow an additional 1 Mt to be exported annually. The Phase 2 expansion commenced in 2005 will increase capacity to 44 Mtpa in 2007.

**Port of Gladstone:** The R.G.Tanna Coal Terminal is undergoing a \$600 million expansion from 40 to 68 Mtpa which is due for completion in mid-2007. The new infrastructure includes a third rail unloading station, a third shiploader, two additional coal stockpiles and a fourth berth. The capacity of Barney Point is being expanded from 5 to 7 Mtpa. The Central Queensland Port Authority plans to spend \$450 million to develop Phase 1 of a new coal terminal at Wiggins Island near Gladstone. Phase 1 of the new terminal would handle up to 20 Mtpa from 2010 and when fully developed at a total cost of \$1.8 billion would have a capacity of 70 Mtpa. **Fisherman Island Coal Terminal** capacity is being increased from 5 to 7 Mtpa.

In New South Wales at the Port of Newcastle, **Port Waratah Coal Services** (PWCS) commenced construction of a \$170 million project in November 2005 to raise loading capacity at the Kooragang Coal Terminal from 89 Mtpa to 102 Mtpa by late 2007. The Newcastle Coal Infrastructure Group is proposing to construct a \$500 million coal terminal with a capacity of 45 to 60 Mtpa with an initial 30 Mtpa first stage operating by 2009.

In Western Australia the **Bunbury Port Authority** is investigating the feasibility of developing facilities to handle and export up to 10 Mtpa of coal.

The amount of coal transported by rail to Queensland ports for export is expected to increase to at least 210 Mtpa by 2010. A \$20 million feasibility study is investigating the 78 km Northern Missing Rail Link between Goonyella and Newlands. A \$500 million 220 km project called the Southern Missing Rail Link plans to connect the Surat Basin to the Port of Gladstone. The Australian Rail and Track Corporation plans to invest \$152 million to upgrade the 452 km track and signalling that make up the Hunter Valley network. The investment program aims to increase the capacity from 85 to 100 Mtpa by 2008. In November 2006 the \$80 million Sandgate Rail Flyover was opened removing a significant bottleneck. Further projects will increase the Hunter Valley rail network to a capacity of 145 Mtpa by 2011.

## RESEARCH AND DEVELOPMENT

In March 2006 the Australian black coal industry committed \$300 million over the next five years to advance technologies to cut greenhouse gas emissions. The "Coal21 Fund" is an extension of the COAL21 program launched in 2004 by industry and government to identify greenhouse gas abatement technologies. A \$9 million International Coal Centre is planned to be built in Blackwater, Queensland, with funding support from the Australian and State Governments and major Queensland coal companies. The centre is expected to be open in mid-2008 and will include an education and community centre, exhibition space, a theatre and café merchandise outlet. The Australian Coal Association Research Program (ACARP) is funded by a five cent per tonne levy on coal mined. ACARP's mission is to research, develop and demonstrate technologies which lead to safe, sustainable production and utilisation of coal.

**ZeroGen Pty Ltd** is proposing to build and operate a 100 MW demonstration plant which integrates the gasification of coal with capture and storage of CO<sub>2</sub> emissions for the generation of low emission base load electricity. Construction at Stanwell in Queensland is due to commence in 2008 with completion in 2010. Compressed CO<sub>2</sub> will be transported by a 220 km pipeline to the Denison Trough region for injection into saline aquifers up to 2 km below surface. Sunshine Gas began drilling in the Denison Trough in June 2006 to test the reservoirs suitability for accepting CO<sub>2</sub> storage.

**CSEnergy** and partners propose to demonstrate the feasibility of the Oxyfuel Project at the Callide A power station in Queensland. The \$188 million Oxyfuel Project involves modifying a coal fired boiler to burn coal in a mixture of oxygen and recycled flue gas instead of air. This produces a concentrated stream of CO<sub>2</sub> suitable for capture, transport and storage in the Denison Trough 350 km to the west. Construction of the demonstration plant is expected to commence in mid-2007 followed by a five year demonstration of the technology from mid-2008. In October 2006 the Oxyfuel Project received \$50 million from the Australian Government's Low Emissions Technology Development Fund.

## Brown Coal

Brown coal, also called lignite, is the lowest rank coal and is used mainly as a fuel at mine mouth power stations. Brown coal is brownish-black, has a high moisture content (up to 66%), high ash content and a low heating value. In Australia brown coal deposits occur in all States and are Tertiary in age (15 to 50 million years old). Brown coal is mined in Victoria only and is used mainly for power generation with some used as fertiliser and to make about 1 Mtpa of briquettes for industrial and domestic heating. Australian Char Pty Ltd produces brown coal char with a production capacity of 80,000 tpa. As a matter of interest the Loy Yang mine in May 2006 unearthed a well preserved 3 m long tree trunk.

### Resources

Recoverable EDR for 2006 was 37.3 Gt a decrease of 0.3% from 2005. Recoverable paramarginal demonstrated resources and subeconomic demonstrated resources remained unchanged at 39.0 Gt and 16.3 Gt respectively. Recoverable inferred resources also remained unchanged at 100.8 Gt. Victoria accounts for more than 96% of Australia's identified resources of brown coal. All EDR is located in Victoria and about 90% of the total EDR is located in the La Trobe Valley.

### Accessible EDR

Approximately 80% of brown coal EDR is accessible. Quarantined resources include the APM Mill site, which had a 50 year mining ban imposed in 1980, the Holey Plains State Park and the Morwell township area. The resource life of the accessible EDR of 29.8 Gt is close to 450 years.

### JORC Reserves

Currently there are no brown coal resource estimates that are JORC Code compliant. However, Geoscience Australia has estimated reserves at the operating mines from published information. These estimates are that reserves are about 4.9 Gt with almost 36% being at Loy Yang. The resource life of published reserves is in excess of 70 years.

## Exploration

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

## Production

Australian brown coal production for 2005–06 was 67.7 Mt (valued at \$849 million) and all was from Victoria. The La Trobe Valley mines of Yallourn (17.5 Mtpa), Hazelwood (18.5 Mtpa) and Loy Yang (30 Mtpa) produce about 98% of Australia's brown coal. Locally significant brown coal operations occur at Anglesea (1.0 Mtpa) and Maddingley (20 ktpa).

## World Ranking

Australia has about 24% of world recoverable brown coal EDR and is ranked first. However, Australia produces about 8% of the world's brown coal and is ranked fifth largest producer after Germany (22%), Russia (10%), USA (9%) and Greece (8%).

## Industry Developments

Asia Pacific Coal and Steel Pty Ltd (100% owned by Environmental Solutions International Ltd) commenced construction of a Coldry commercial drying plant at Bacchus Marsh in October 2006 with the aim of exporting up to 3 Mtpa of brown coal pellets to Asia by 2008. A 10,000 tpa Coldry process pilot plant has been in operation since February 2004. The Coldry process was developed at Melbourne University in the 1980's to reduce moisture content by up to 78% and raise the calorific value from 8 to 23 megajoules per kilogram. The pellets also could cut emissions from the current LaTrobe Valley power stations by as much as 10%.

In June 2006 construction commenced on a \$6.3 million coal drying demonstration plant at Loy Yang. The plant will use a process called Mechanical Thermal Expression (MTE) to reduce the moisture content of brown coal. The Australian and Victorian Governments have each provided \$2.2 million for the project with the remaining \$1.9 million being provided by the power suppliers in the region. Commissioning is expected in January 2007 and the overall project will conclude in mid-2007. The MTE plant is expected to be able to process up to 15 tonnes per hour and if successful stakeholders hope to retrofit existing power plants. The use of dried brown coal would reduce CO<sub>2</sub> emissions by about 5% in existing plants and by about 30% in new plants. If the demonstration plant is successful a commercial scale pilot plant could be in place by 2008.

LaTrobe Lignite Developments Pty Ltd plans to use a technology called Brown Coal Densification which removes water from brown coal to produce low moisture coal, char and char based products. Plans exist to move from a small demonstration plant near Bacchus Marsh to a \$400 million 100 MW plant in the LaTrobe Valley by 2010 and a 1,000 MW plant by 2015.

HRL Ltd and Harbin Power Equipment Group Corporation signed a Memorandum Of Understanding in early 2006 to develop a \$750 million 400 MW demonstration power station. The project will use HRL's Integrated Drying and Gasification Combined Cycle (IDGCC) technology which is anticipated to deliver a 30% reduction in greenhouse gas emissions and a 50% reduction in water usage compared with current power stations in the LaTrobe Valley. Construction is expected to start in late 2007 and be completed within two years.

In mid-2006 Anglo American and the Shell Group formed an alliance to develop the Monash Energy project. Monash Energy plans to build a \$300 to 400 million demonstration plant next to the Loy Yang power stations. In 2005, \$2.5 million was spent on successfully testing the drying and gasification performance of a 1,500 t bulk sample in Germany. The demonstration plant design and Environmental Impact Statement approvals will be undertaken to enable construction to commence in 2008 and commissioning to occur in 2010. If viable, a new \$5 billion 25 Mtpa coal mine, drying and gasification plant, CO<sub>2</sub> capture and storage system and Fischer-Tropsch gas to liquids plant (60,000 barrels per day) will be constructed by 2016.

In August 2006 the Victorian Government announced a \$12 million Brown Coal Research and Development Grants Program to develop new low emission technologies associated with power generation. The grants program is part of the Victorian Government's \$103.5 million Energy Technology Innovation Strategy which is coordinating Victoria's research into energy technologies.

## Coal Bed Methane

Coal Bed Methane (CBM) is naturally occurring methane gas ( $\text{CH}_4$ ) in coal seams. It is also referred to as Coal Seam Methane (CSM) and Coal Seam Gas (CSG). Methane that is associated with coal mining operations is called Coal Mine Methane (CMM). Methane was long considered a major problem in underground coal mining, but CBM is now recognised as a valuable resource. The methane is usually associated with small quantities of carbon dioxide, other hydrocarbons and nitrogen.

CBM and CMM can be used either as feed for pipeline gas or as a fuel for on-site electric power generation. Pipeline gas is supplied to regional centres and cities for such uses as power generation, industrial facilities and mains gas for home heating, cooking and hot water. Water is produced as a by-product of CBM production and after treatment this water may be suitable for use as town water supply, industrial facilities (eg coal mines and abattoirs), feedlots and high-value horticultural development. Other untreated CBM water uses include aquaculture, recharging aquifers, habitat creation (eg wetlands) and recreation (eg sailing, boating, picnic spots).

### Resources

As at December 2006 the 2P reserves (proven plus probable) of CBM in Australia were 4,642 Petajoules (PJ) or over 60 years of production life at current rates of extraction of 75 PJ per annum. Queensland has 4,559 PJ (or 98%) of the 2P reserves with the remainder (83 PJ) at the Camden operation in New South Wales. Of the Australian reserves 3,290 PJ (or 71%) occur in the Bowen Basin and 1,269 PJ (or 27%) occur in the Surat Basin. The Fairview project (operated by Santos Ltd) in the Bowen Basin has 1,487 PJ of 2P reserves or 32% of Australia's CBM reserves. Note that there are no CMM reserves.

### Exploration Expenditure

Data relating to exploration expenditure are not published by ABS on either a state or national basis. CBM exploration involves locating highly productive areas, known as "sweet spots" or "fairways". Initially, CBM was mainly sought within the Permian coal seams of the Bowen and Sydney Basins. However, since the year 2000, CBM exploration has also targeted the relatively shallow depths of the lower rank coal seams of the Jurassic age Surat and Clarence-Moreton Basins. Although these seams have lower gas contents than high rank Permian age coal these lower rank coals at shallow depths (100 to 600 m) are more permeable and CBM can be more easily desorbed (or extracted), resulting in higher recovery factors. Brown coal (or lignite) of Tertiary age has also become a target for CBM exploration in the Otway Basin in Victoria. Other prospective coal basins that have been targeted by CBM explorers include the Cooper, Gunnedah, Gloucester, Galilee, Ipswich, Murray, Nagoorin, Perth and Styx Basins. However, the Bowen Basin remains the most actively explored and developed basin in Australia for CBM. The basin's share of CBM drilling activity was about 45% of Australia's total in 2005.

### Production

In Australia the commercial production of CBM (including CMM) was zero in 1995. In 2003, CBM production was 40 PJ and by 2006 production had almost doubled to 75 PJ with 71 PJ being produced in Queensland. In 2006, CBM met about 60% of the total Queensland gas demand of 117 PJ. In 2006, CBM supplied about 15% of the east coast gas market. However by 2020 CBM is predicted to supply 35 to 50% of the gas demand in eastern Australia, as the Cooper Basin gas reserves become depleted. In 2004, CBM accounted for about 4% of Australia's total natural gas consumption.



## Industry Developments

### QUEENSLAND

Queensland CBM and CMM operations and developments include:

**Anglo Coal Australia Pty Ltd:** The Dawson Valley and Mungi CBM operations produce about 3.7 PJ/annum. The Moura mine CMM operation produces about 5.5 PJ/annum. These projects are connected to the Wallumbilla-Gladstone pipeline.

**Santos Ltd:** The Fairview and Scotia CBM operations produce about 24.7 PJ/annum.

**Origin Energy:** The Peat CBM operation produces about 4.5 PJ/annum. Spring Gully commenced producing about 14.4 PJ/annum in 2005. A 1,000 MW combined cycle gas fired power station is planned to be commissioned in 2009 consuming about 70 PJ/annum of Spring Gully CBM.

**Queensland Gas Company:** The Berwyndale South CBM operation commenced in 2006 at a rate of about 6.3 PJ/annum. A 135 MW combined cycle gas fired power station is planned to be commissioned in 2009.

**CH4 Gas/Arrow Energy:** The Moranbah CBM operation produces about 16.6 PJ/annum for a combined cycle gas fired power station in Townsville. The Kogan North CBM operation commenced producing about 1.6 PJ/annum in 2006. In 2006 the Daadine CBM operation commenced supplying about 2 PJ/annum to a 27 MW gas fired power station. In February 2007 the Tipton West CBM operation commenced supplying about 6 PJ/annum to the Braemar power station.

**Energy Developments Ltd:** In 2006 a CMM operation commenced at the German Creek Colliery supplying about 2.5 PJ/annum to a 32 MW gas turbine.

**Envirogen Pty Ltd:** In 2006 a CMM operation commenced at the Oaky Creek Colliery supplying gas to a 13 MW gas turbine.

### NEW SOUTH WALES

New South Wales CBM and CMM operations and developments include:

**Sydney Gas Ltd:** The Camden CBM operation produces about 3.5 PJ/annum.

**Metgasco Ltd:** Propose to develop a 30 MW CBM fuelled power station at Casino.

**Energy Developments Ltd:** The Appin and Westcliff (Tower) Collieries CMM operations supply 7.5 PJ/annum to power stations with a total capacity of 97 MW.

**Envirogen Pty Ltd:** The Tahmoor Colliery CMM operation fuels a 5 MW gas turbine and the Teralba Colliery CMM operation fuels a 6 MW gas turbine. The Glennies Creek Colliery CMM operation fuelling a 10 MW power station is due to commence in mid-2007.

## 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, Cadia Ridgeway and Tritton (NSW), Ernest Henry, Osborne, and Mt Gordon (Qld), Nifty and Golden Grove (WA) and Mt Lyell (Tas). Copper and copper alloys are used in building construction and electrical equipment such as electrical cables as well as in industrial machinery and equipment.

### Resources

In 2006, Australia's EDR of copper rose by 1 Mt to 42.4 Mt, an increase of 2% for the year. South Australia has the largest EDR at 26 Mt, which decreased by 2% in 2006 to be around 62% of the national total. The majority of these resources are associated with the Olympic Dam deposit. Queensland has the second largest EDR with 17% of the national total, followed by New South Wales (11%), and Western Australia (7%). EDR in New South Wales increased by 2 Mt following an upgrade of resources at the Cadia East deposit.

Subeconomic demonstrated resources increased by 23% to 7.5 Mt, made up of 6.4 Mt in the paramarginal category and 1.1 Mt in the submarginal category. The increase of 1.6 Mt in paramarginal demonstrated resources compared to 2005 reflects activity in the Mt Isa region of Queensland where a range of deposits are being evaluated, in Western Australia at the Spinifex Ridge Mo-Cu deposit and in the Northern Territory at the Browns deposit. Most of the paramarginal demonstrated resources are in Queensland and Western Australia with 43% and 22% respectively, followed by South Australia with 12%.

Inferred Resources rose by 15% to just under 35 Mt in 2006. South Australia holds 65% of Australia's Inferred Resources followed by Queensland 15%, Western Australia 11% and New South Wales 8%.

### Accessible EDR

All copper EDR is accessible.

### JORC Reserves

JORC Code reserves account for around 43% 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 rose by 68% in 2006 to \$177.5 million. Expenditure in South Australia (\$83.2 million) was 47% of all copper exploration and was directed mainly to the search for further Olympic Dam style mineralisation in the Gawler Craton and resource definition drilling at Olympic Dam and Prominent Hill. Queensland had 27% of spending on exploration for copper across a range of projects and New South Wales 14%, with the remaining 12% distributed largely in Western Australia with 8% and to a lesser extent in the Northern Territory, Tasmania and Victoria. Expenditure on exploration for copper made up 12% of all mineral exploration. Significant exploration results reported during 2006 include:

**Rocklands (Qld):** Cudoco Ltd reported an Inferred Resource for this new discovery of 25 Mt at 1.57% Cu, 818ppm Co and 0.2g/t Au. Drilling intersections included 78 m at 2.31% Cu and 33 m at 3.86% Cu, including 13 m at 6.39% Cu and 8 m at 1.36g/t Au. Subsequent intersections include one drill hole with more than 100 m of visual native copper.

**Golden Grove (WA):** Two Cu-Zn discoveries made in 2006 have the potential to significantly extend the mine's life beyond the current seven years. Drilling beneath the Xantho orebody at Gossan Hill intersected 51 m at 6.1% Cu, 1.8% Zn and 1.1 g/t Au (from 1,000 m), including 23 m at 9.8% Cu, 3.9% Zn and 1.8 g/t Au. Drilling beneath the Scuddles mine intersected 45.7 m at 2.4% Cu from 1,629 m, and 6.5 m at 26.6% Zn from 1,675 m. The 6 km long Scuddles-Gossan Hill system lies within a 34 km belt of volcanic rocks with the potential to host additional volcanic hosted massive sulphide (VHMS) systems. Testing of the larger area is underway along with a program in the vicinity of existing orebodies seeking repetitions at depth or orebody extensions.

### Production

In 2006, Australia's mine production of copper totalled 875 kt of contained copper, 5% lower than in 2005 (921 kt). Queensland continued to dominate production with 353 kt, largely from Mt Isa, although this was 12% less than in 2005. Queensland accounted for 40% of Australian production, down from 43% in 2005. New South Wales surpassed South Australia as the second largest producer with an increase of 11% to 210 kt or 24% of total production, mostly from Cadia Ridgeway and Northparkes. In South Australia, Olympic Dam produced all of the State's output of 183 kt in 2006 which was 14% less than in 2005. Other production saw Western Australia produce 98 kt, up 11%, and Tasmania produce 31 kt, up 3%.

The value of Australia's exports of copper concentrates and refined copper in 2006 totalled just under \$6.6 billion, 66% more than in 2005 (\$4 billion) and 4% of the value of total merchandise exports.

The increase reflects higher copper prices in 2006 with the average up by 86% to \$9,003/t compared to the average of \$4,852/t in 2005. In line with decreased production of copper in 2006 was an 8% decrease in exports to 724 kt.

### World Ranking

Based on USGS data for other countries, Australia has the second largest EDR of copper (8%) after Chile (30%) and ahead of the USA and Indonesia (both 7%) and Peru, Poland and Mexico (all 6%). As a producer, Australia ranks fourth in the world with 6% after Chile (35%), the USA (8%) and Peru (7%).

### Industry Developments

**Mt Isa (Qld):** Copper-in-concentrate production in 2006 from Xstrata Plc's Mt Isa and Ernest Henry operations totalled 278 kt, a decrease of 9% on 2005. At Mt Isa, head grades of 3.42% Cu and record higher ore production gave a copper-in-concentrate result of 194 kt. This was offset by Ernest Henry production at 84 kt of copper-in-concentrate, 35% lower than 2005. This reflected a 27% decrease in ore grade, to 0.89% Cu, and 10% less throughput because of harder ore. Smelter production of 213 kt copper was 3% lower than in 2005, predominantly due to a planned month long shutdown of the smelter in September 2006 to re-brick the ISASMELT furnace and to enable the commissioning of the second rotary holding furnace. The Townsville copper refinery produced 209 kt of saleable cathode, 5% less than in 2005 due to the lower anode supply from the Mt Isa smelter. During 2007, the copper smelter and refinery capacities will continue to be expanded to the planned production rate of 300 ktpa through the completion of a series of projects. This is designed to match the total copper-in-concentrate production from the Mt Isa and Ernest Henry copper mines.

At the Enterprise copper mine, access development to the Northern 3500 underground copper ore body was completed at the end of 2006 at a total capital cost of \$38 million. Production from this additional high-grade mining zone will be progressively increased during 2007 to enable the mine to maintain its rated capacity of 3.5 Mtpa and improve use of the existing hoisting and concentrator capacity. Pre-feasibility work is to commence in 2007 on evaluating the potential to exploit significant known low grade resources contained within the 500 ore body (70 Mt at 1% Cu) and the "halo" mineralisation surrounding the 1100 ore body through bulk mining methods.

**Olympic Dam (SA):** Production for 2006 totalled 183 kt of copper cathode. This was 14% less than in 2005, which was attributed to maintenance activities at Olympic Dam and the variability of ore sources and their grade. BHP Billiton continued a pre-feasibility study (initiated by WMC) to examine capacity expansion options with open-pit being a preferred mining method. The project would approximately double copper production. This would require as a consequence, major infrastructure for water, energy, transport and a township expansion. The scheduled timeframe for the project is feasibility conclusion by early 2009 and construction from 2009 to 2013, resulting in operation of the expanded facilities from 2013 onwards.

**Prominent Hill (SA):** The Bankable Feasibility Study was completed on schedule in August 2006 and Oxiana Ltd formally announced it would proceed with the \$775 million development of Prominent Hill, which will produce an average 84 ktpa of copper-in-concentrate and 115,000 ozs gold per annum for 10 years. Production of the first commercial copper and gold concentrates is scheduled for the third quarter of 2008. Development includes an open-pit mine, a conventional grinding and flotation processing plant with an 8 Mtpa capacity, construction of a permanent village to accommodate a workforce of approximately 400 people and construction of a haulage road, power line and bore field. Pre-stripping of the 100 m of sedimentary cover commenced in October 2006 with the orebody due to be reached in early 2008. Copper and gold concentrates will be transported by 140 t road trains to a rail siding at Wirrada and shipped in 10,000 to 20,000 t lots to smelters in Asia and Australia.

**Telfer (WA):** After almost two years under construction, Newcrest Mining Ltd's re-development of Telfer as a gold-copper mine completed its first full year of production in 2005–06. The 650,016 ozs

of gold and 38,374 t of copper produced was nearly all from the open pit supergene ore which proved more complex than expected and required further drilling and sampling to improve predictability of ore grades. The supergene ore is confined to the open cut and its proportion of total ore treated will diminish as production from the underground mine increases to its planned 4 Mtpa rate in 2007.

**Cadia East (NSW):** Newcrest updated the Cadia East Mineral Resource as 21.9 Mozs Au and 3.6 Mt Cu. This occurs in two zones – an open pit zone, for which an initial Ore Reserve of 1.8 Mozs Au and 0.63 Mt Cu was reported, and an underground zone, for which the Ore Reserve was increased by 1.3 Mozs Au and 0.12 Mt Cu to a new total of 7.3 Mozs Au and 0.75 Mt Cu. The decline for the Cadia East Underground Panel Cave feasibility study advanced 1.5 km of the total 7 kms that is required to access the orebody. Newcrest reports that Cadia East's Panel Cave will be Australia's largest underground mine with an expected life of more than 30 years.

**Browns (NT):** Compass Resources signed a binding contract with Hunan Nonferrous Group (HNC) which will fund development of the \$69 million Browns base metals oxide project. The operation is expected to produce about 10 kt copper cathode, 1 kt cobalt and 750 t nickel annually from the 10-year, 1 Mtpa project. Compass has relocated the solvent extraction plant and most of the electrowinning plant from the Cawse laterite project in WA. HNC also has committed to provide all the capital required to develop a potential 4 Mtpa sulphide operation at Browns. Brokers have estimated potential capital costs of a 2 Mtpa operation to be in the order of \$300-400 million.

**Lady Annie (Qld):** CopperCo is spending around \$80 million developing a 19 ktpa copper producing operation. From a resource of 21.5 Mt at 0.9% Cu for 194 kt of contained copper, 16.8 Mt is to be crushed and stacked at an average grade of 0.94% containing 157 kt copper. CopperCo plans to mine five ore bodies – Lady Annie, Mt Clarke, Flying Horse, Mt Kelly Workings and Swagman – by conventional open pit mining, with Mt Clarke to be mined first.

**Redbank (NT):** Redbank Mines Ltd is currently vat-leaching high grade oxide stockpiles under the project's first stage to produce 1 ktpa Cu. A proposed Stage 2 commencing in 2008 will mine oxides from the Bluff, Redbank and Azurite breccia pipes to increase production to 3 ktpa Cu. Stage 3, involving mining of underlying sulphides for floatation is proposed to double Cu output to 6 ktpa from a resource base of 4.2 Mt at 1.5% Cu.

**Mt Watson (Qld):** Matrix Metals Ltd is spending \$10 million developing its Leichhardt project consisting of the Mt Watson mine, refurbishment of the Mt Cuthbert processing plant 25 km south, and construction of a haul road. Production of 5.5 ktpa copper cathode for 4 years is planned from an oxide resource of around 8 Mt at 1% Cu. Stage 2 development proposes increasing to 10 ktpa Cu and is estimated to cost an additional \$5 million for the plant upgrade.

**Balcooma (Qld):** Kagara Zinc Ltd announced an initial copper reserve of 2.35 Mt at 3.4% Cu, 15g/t Ag and 0.37 g/t Au within a 180 m deep pit. Production is scheduled to start in 2007 at a rate of 30 ktpa of contained copper with the bulk of the ore likely to be processed through the Thalanga treatment plant.

**Roseby (Qld):** A feasibility study of the proposed Roseby mining and processing operation was completed in October 2006. The proposed 8 Mtpa open pit operation is forecast to produce up to 34 ktpa of copper from the start of 2009 and during the first four years, 14,700 ozs of gold per annum. The current estimated life of the project is 8.5 years at a capital cost of \$388 million with a total resource of 127 Mt at 0.73% Cu and 0.06g/t Au.

**Mutooroo (SA):** Havilah Resources have been funded \$3 million by Heilongjiang Resources (HJR) for a feasibility study aimed at determining a JORC Code measured resource and a minimum production schedule of about 10 ktpa Cu and 1 ktpa Co. Thereafter HJR will fund 100% of the mine development until production for a share of up to 50% of mine output. Scoping studies at Mutooroo based on drilling to date, indicate the deposit contains at least 11 Mt at 1.1% Cu and 0.1% Co, and deeper ore sections indicate grades of 2% Cu and 0.2% Co.

## 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 form 150–200 km below the Earth's surface at high temperatures (1,050–1,200°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 can 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 109.9 Mc and industrial 114.3 Mc, both down 12% compared with 2005 due to production at the Argyle mine in Western Australia and resource re-assessment.

### 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 2006 was \$27.8 million, up 22% on 2005. Exploration continues to be concentrated in Western Australia, notably the Kimberley region, and in the Northern Territory.

### Production

Australia produced 29.3 Mc of diamond in 2006, 1.4 Mc less than in 2005, which now ranks as the world's fourth largest producer of diamond by weight after Russia, Botswana and Congo. As a producer of gem/near gem diamond, Australia is the third largest after Botswana and Russia, and as producer of industrial grade diamond Australia is the equal second largest alongside Russia and after Congo.

Production was almost entirely from the Argyle mine, which produced 29.1 Mc – mostly industrial and cheap diamonds with an average price of US\$15-16 per carat, making it the leading global producer. Production was 5% less than in 2005 due to mining constraints within the deepening open pit. Production is expected to decrease further to about 60% of Argyle's historical annual average of 34 Mc at a similar quality as the open pit winds down and underground production ramps up over the next five years.

Production from Kimberley Diamond's Ellendale mine in the West Kimberley region increased to 152,000 carats in 2005–06, up from 123,000 carats in the previous year. The average grade for the period was 7.2 cpht (6.8 cpht in 2004–05). The average sale price was lower at US\$173 per carat (US\$226 in 2004–05) due to the introduction to the sales blend of lower quality Ellendale 4 pipe diamonds. Ellendale is noted for high-value fancy yellow gem diamonds, and this is reflected in the average sale price for pipe 9 East diamonds of US\$348 per carat.



At the Merlin operation in the Northern Territory, North Australian Diamonds reported a total diamond recovery for 2006 of 11,811 carats, of which 5,415 carats were recovered during October and November. The overall average price achieved is US\$144 per carat with the highest value stone, a 10.6 carat white octahedral diamond, selling for US\$153,170 which equates to US\$14,450 per carat.

### World Ranking

Australia's EDR of industrial diamond ranks third (19% of current world total EDR), after the Congo (Kinshasa) and Botswana (25% and 22% respectively). Detailed data are not available on world resources of gem/near gem diamond but Australia has stocks amongst the largest for this category.

### Industry Developments

**Argyle (WA):** Rio Tinto approved the development of an underground block cave mine under the AK1 open pit in late 2005. It also approved an open pit cutback on the Northern Bowl to facilitate the transition from open pit to underground mining. The capital cost of the underground mine is expected to be US\$760 million, and the cutback US\$150 million. Construction started in February 2006. By the end of 2006, 10,600 m of underground development in four main access declines had been completed. In late 2006 the first of the underground declines reached the required depth for ore extraction. The underground block cave undercut is expected to be initiated on schedule in 2008 and extend the life of the mine to 2018. Softer diamond markets resulted in excess of US\$100 million of surplus rough Argyle diamonds being held in inventory at the end of the year.

**Ellendale (WA):** At Ellendale Pipe 4, an open cut mine and 4.4 Mtpa processing plant was successfully commissioned in September 2006. Forecast production from Ellendale 4 is more than 2.7 Mc over a seven year life. A two-stage expansion of the existing 2.2 Mtpa Ellendale 9 East processing plant is also in progress and in 2006 capacity was increased by 50% to 3.3 Mtpa. The second stage, involving installation of a high pressure rolls crusher will lift production to 4.4 Mtpa. The crusher will enable treatment of the 30% of ore which was previously being reported as encapsulated lights. Test work indicated that 20% of diamonds were not being recovered from this ore. The upgrades are expected to reduce cash costs by up to 20% and contribute to an increase in total Ellendale output from 120,000 to over 600,000 carats per year.

**Merlin (NT):** The Merlin operation was previously owned by Ashton/Rio Tinto, which recovered 500,000 carats from nine pits from 1998 to 2003. North Australian Diamonds Ltd (NAD) determined that previously reconciled production grades may have understated the true kimberlite grades by more than 25%. As the first stage of its redevelopment of the Merlin operation, NAD began re-processing the x-ray sorthouse tailings in July 2005 and this was completed in mid-2006 with around 13,000 carats recovered in total. Stage 2 of the redevelopment was undertaken in 2006 and involved trial mining of re-optimised pits and remnant ore and processing ore contained in tailings stockpiles. This helped establish run of mine values for use in the Stage 3 pre-feasibility study into underground development of the Gawain and Ywain pipes and a dual cut back of the Palomides & Sacamore open pits.

## Gold

Gold prices remained strong throughout 2006 but this strength could not maintain exploration expenditure which fell in the face of very strong metal prices which underpinned substantial growth in base metal exploration. Production fell in 2006 but with developments currently occurring is expected to increase in 2007. Exploration generated a large number of intersections of economic significance justifying further work but there remained a lack of discovery of large or world-class deposits.

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.

## Resources

Australia's gold resources occur and are mined in all States and the Northern Territory. At the end of 2006, total Australian gold resources were 312 t higher than at the end of 2005. After allowing for the replacement of those resources lost to production (246t) newly delineated resources added to the national inventory totalled 447 t (13 Mozs) in 2006.

Australia's EDR rose by 256 t (8.2 Mozs) in 2006 to 5481 t and accounted for 80% of total demonstrated resources, an increase on the 78% share in 2005. In 2006, EDR increased in New South Wales, Western Australia and the Northern Territory. Western Australia continued to dominate EDR with 54% of the national total which was an unchanged share. In 2006 its EDR was 2938 t. South Australia had the second largest EDR.

Subeconomic demonstrated resources fell by 40 t in 2006 as paramarginal demonstrated resources fell and submarginal demonstrated resources rose. Resources in the paramarginal category fell by 50 t to 1265 t with Western Australian paramarginal demonstrated resources falling by 34 t to 921 t which remained at 73% of total paramarginal demonstrated resources. Increases occurred in the paramarginal category only in the Northern Territory. The submarginal demonstrated resources rose by 10 t to 128 t, over half of which was in Western Australia.

Inferred resources rose by 96 t to 4499 t. Western Australia continued to dominate inferred resources accounting for about 45% of total inferred resources which was a similar level to 2005.

## Accessible EDR

EDR for gold are essentially unencumbered, with less than 1% is in any form of restricted area. At Australia's 2006 rate of production, EDR is sufficient for about 22 years production. If, however, resources only classified as reserves under the JORC Code are considered, they will support only 14 years at the 2006 production rate. This is slightly higher than the 2005 reserve:production ratio. These are average figures and that there are some operations that may continue after these periods and there are others that will close before the end of those periods. These figures continue to highlight 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 2006 just under 61% of EDR fell into the JORC reserves.

## Exploration

Based on the 2006 calendar year spending on exploration reported by ABS, gold remained the dominant target in 2006 but its share of total spending fell sharply from 34% in 2005 to 29% in 2006. This substantial fall occurred despite a 12% increase in gold expenditure to \$429.8 million. The reduced share resulted from increased spending on almost all other commodities on the back of strong international demand for commodities and high or record metal prices. Western Australia continued to dominate gold exploration by attracting \$259.7 million, \$18.4 million more than in 2005. However, its share of total gold exploration fell to 60.4%. All other regions had gold exploration during the year and encouraging results were reported from them. Selected highlights which are indicative of the year's activity are reported at the end of this section.

It should be noted that ABS data reported on above do not include exploration for copper-gold mineralisation where the explorer nominates copper as the principal commodity. Such expenditure will be reported as exploration for copper.

On a financial year basis, ABS reported gold exploration spending for 2005–06 was \$399.7 million, a reduction of \$8 million over 2004–05. Increases in Victoria, Queensland, South Australia and Tasmania were insufficient to offset reductions in other jurisdictions. Western Australia was the focus of gold exploration with \$240.3 million (60% of total gold exploration spending).

Data published by the Canadian company Metals Economics Group (MEG) on company exploration budgets for non-ferrous minerals indicates that intended budgets for gold exploration in Australia for 2006 totalled US\$373.9 million (A\$505 million based on the exchange rate used by MEG). This budget was about 17% higher than actual spending reported by ABS. The differences between reported budgets and actual spending on gold exploration may in part have been caused by the rapid increase in base metals exploration resulting in gold budgets being reduced as additional funds were directed to base metals.

The MEG data show that 33% of gold exploration budgets were expected to be directed at grassroots exploration while a further 33% was directed to mine site exploration. The remaining 34% was for late stage exploration. These shares are indicative of the trend to brownfields exploration that Australia has been experiencing in the major commodities.

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 Western Australia's Yilgarn Craton remain a very favourable target, but the reported results that follow suggest that substantial opportunities exist in other provinces. Indicative intersections are noted below.

### NEW SOUTH WALES

- Reconnaissance drilling at the McPhillamys prospect, 35 km SE of Orange, by Alkane Exploration Ltd discovered mineralisation including 24 m @ 2.03g/t Au from 4 m including 5 m @ 5.69g/t Au and 17 m @ 1.50g/t Au while later drilling returned 77 m @ 1.65g/t Au from 140 m and 31 m @ 1.64% Zn, 12g/t Ag and 0.18g/t Au from 64 m.
- Goldminco Corporation released a revised resource estimate for the Discovery Ridge project, near Blayney, of 4.2 Mt @ 1.2g/t Au in the indicated category and 2.4 Mt @ 1.4g/t Au of inferred resources for an aggregate 0.272 Mozs Au.

### NORTHERN TERRITORY

- Tanami Gold NL discovered the Tekapo mineralisation in an unexplored area of its Lake Mackay project 400 km north west of Alice Springs. Intersections of 16 m @ 3.4g/t Au from 29 m, 3 m @ 1.79g/t Au from 10 m and 2 m @ 2.01g/t Au from 22 m were reported. Later drilling yielded copper mineralisation including 4 m @ 2.67% Cu, 2 m @ 0.83% Cu and 4 m @ 0.60% Cu.
- GBS Gold International Inc. released new drill intersections from exploration at the Fountain Head deposit, 70 km north west of Pine Creek. Intersections included 17 m @ 4.4g/t Au, 6 m @ 5.0g/t Au and 29 m @ 4.8g/t Au. The Company will mine the deposit as part of its Union Reefs operation.

### QUEENSLAND

- Extensions to the high-grade mineralisation in the Kilkenny structure at Cracow were reported by Sedimentary Holdings Ltd. Intersections included 49 m (28.3 m estimated true width) @ 4.8g/t Au from 766 m and 9.3 m (7.2 m estimated true width) @ 21g/t Au. Kilkenny is 400 m from and readily accessible by the Crown decline being developed to access the Crown Shoot.
- At the Agate Creek prospect, 80 km south of Georgetown, Renison Consolidated Mines NL reported thick, near-surface mineralisation in the Zig-Zag Fault. Intersections included 61 m @ 0.9g/t Au including 26 m @ 1.5g/t Au. Renison is undertaking a feasibility study into open pit mining at Agate Creek based on a total resource of 13.2 Mt @ 1.0g/t Au (0.428 Moz).
- At the Mount Carlton Project, Conquest Mining Ltd discovered high-grade mineralization. Intersections include 85 m @ 3.39g/t Au, 17.4g/t Ag, and 0.24% Cu from 79 m, 36 m @ 9.93g/t Au 32.7g/t Ag and 0.4% Cu from 92 m, and 21 m @ 1864g/t Ag and 3.52% Cu from 54 m. Project resources were revised to 6.646 Mt at 1.47g/t Au (313,410 oz), 85g/t Ag (18.175 Moz) and 0.39% Cu (25,923 t).

## SOUTH AUSTRALIA

- Drilling by Minotaur Exploration Ltd at the Tunkillia deposit, 145 km NE of Ceduna, intersected significant gold mineralisation in the supergene and primary zones and lower grade gold in the oxide zone. Better intersections included 7 m @ 7.7g/t Au, 3 m @ 8.5g/t Au and 6 m @ 3.9g/t Au. Later drilling appears to confirm the presence of a coherent oxide zone and intersections included 10 m @ 4.2g/t Au and 5 m @ 5.9g/t Au from above bedrock mineralisation and 12 m @ 15.8g/t Au and 5m @ 12.1g/t Au peripheral to known bedrock mineralisation.
- At the old Bird-in-Hand gold mine near Woodside, Maximus Resources Ltd reported high-grade gold mineralisation with an intersection of 6 m (estimated at 4.2 m true width) @ 23.5g/t Au and including 1.5 m @ 78.2g/t Au.

## TASMANIA

- Deep drilling by Lefroy Resources Ltd at the Lefroy project, 40 km north of Launceston, identified the South Pinafore mineralisation 150 m south of the Pinafore Reef. South Pinafore occurs under basalt and intersections included 2 m @ 14.5g/t Au from 101 m.
- Frontier Resources Ltd reported encouraging intersections from drilling at its Panama prospect 25 km NE of Launceston including 0.5 m @ 7.5g/t Au and 0.5 m @ 5.83g/t Au, both from 16 m below surface.

## VICTORIA

- Leviathan Resources Ltd announced high-grade gold intersections at the Tandarra prospect 40 km north of Bendigo. Exploration targeted gold deposits under cover along an interpreted major crustal corridor which includes the Ballarat and Bendigo goldfields. Drilling confirmed quartz veining beneath 40-90m of sediment cover with intersections including 1 m @ 160g/t Au from 104 m, 1 m @ 24.7g/t Au from 84 m and 4 m @ 1.3g/t Au from 70 m.
- Perseverance Corporation Ltd discovered a new zone of sulphide mineralisation at its Fosterville project at Fosterville. It reported that the mineralisation is analogous to the main mineralisation at Fosterville and intersections of 5.1 m @ 5.0g/t Au, 4.0 m @ 6.1g/t Au and 10.4 m @ 2.2g/t Au were returned.
- Goldstar Resources NL advanced the Walhalla project with underground development, bulk sampling and drilling at the Eureka and Tubal Cain prospects. Encouraging drill results including 1.05 m @ 1,869g/t Au.

## WESTERN AUSTRALIA

- Successful exploration continued to be reported by Avoca Resources Ltd from its Trident deposit at Higginsville. Wide zones of high-grade mineralisation were identified 100–150 m below the Western Zone mineralisation including 25 m @ 4.0g/t Au and 14 m @ 4.7g/t Au. Drilling in the Athena Lodes at Trident returned 3 m @ 63g/t Au, 3m @ 18.2g/t Au and 4 m @ 8.3g/t Au. Avoca reported that resources at its Higginsville project were 8.7 Mt @ 4.0g/t Au (1.11 Moz) of which 4.3 Mt @ 6.2g/t Au was in the Trident mineralisation.
- Drilling at the Independence Group NL and AngloGold Ashanti Ltd joint venture at Tropicana, E of Laverton, continued to yield results that suggest potential for a large deposit. Indicative intersections reported included, from the Tropicana Zone, 30 m @ 3.0g/t Au and from the Havana zone 63 m @ 3.0g/t Au, 7 m @ 3.9g/t Au and 11 m @ 3.4g/t Au. At the Rusty Nail prospect 5 m @ 3.4g/t Au was reported.
- At the Doolgunna project, 150 km north of Meekatharra, Sandfire Resources NL reported encouraging intersections from the Old Highway prospect including 8 m @ 2.81g/t Au, 24 m @ 3.22g/t Au which included 12 m @ 6.42g/t Au and 48 m @ 5.90g/t Au which included 16 m @ 11.28g/t Au. The discovery of the Cow Hole Bore mineralisation with intersections of 4 m @ 5.50g/t Au and 4 m @ 7.43g/t Au was announced as was an intersection of 14 m @ 10.40g/t Au from the East Shed Well prospect.

- At the Brilliant prospect, 75 km ENE of Kalgoorlie, Shannon Resources Ltd reported high-grade intersections including 52 m @ 5.44g/t Au including 7 m @ 25.14g/t Au and 29 m @ 5.28g/t Au including 3 m @ 30.63g/t Au.
- In the East Kimberley region, Northern Star Resources Ltd reported encouraging intersections from drilling at its Range prospect 130 km north of Halls Creek. Intersections included 4 m @ 15.06g/t Au and 7.30g/t Ag from 21 m, including 1m @ 57.15g/t Au and 15.70g/t Ag. Other results included 4 m @ 2.05g/t Au and 1.31g/t Ag and 1 m @ 3.50g/t Au and 1.80g/t Ag.
- Agincourt Resources Ltd's drilling adjacent to the main East Lode at its Wiluna open pit found a new high-grade lens which is expected to improve the economics of a cutback option for the East Pit. Intersections included 56 m @ 10.8g/t Au and 24 m @ 13.4g/t Au, both true width. Agincourt also reported the discovery of high-grade mineralisation, Henry 5, between its Calais and Woodley systems at Wiluna with an 18 m (estimated true width of 9.0 m) intersection @ 10.42g/t Au and 8.8 m @ 18.7g/t Au. At Calais, high-grade intersections were reported from outside the reserve envelope including 10.5 m @ 31.3g/t Au, 23.0 m @ 11.4g/t Au and 14.5 m @ 14.9g/t Au.
- In drilling aimed at defining resources to supplement resources at its Yagahong deposit at Gabanintha, 45 km SE of Meekatharra, Reward Minerals Ltd reported intersections of 5 m @ 14.57g/t Au and 6 m @ 5.00g/t Au from the Golden Hope North prospect.

## Copper-Gold

### NEW SOUTH WALES

- Golden Cross Resources Ltd announced a new resource for its Copper Hill deposit near Molong with indicated resources increasing to 79.9 Mt @ 0.36% Cu and 0.35g/t Au and an inferred resource of 56.1 Mt @ 0.30% Cu and 0.27g/t Au (total contained metal of 455,000 t Cu and 1.4 Mozs Au). Ongoing exploration located mineralisation 400 m north of Copper Hill at Copper Hill North where intersections included 188 m @ 0.39% Cu and 0.16g/t Au and 184 m @ 0.43% Cu and 0.15g/t Au.
- Goldminco Corporation reported intersections at the Estoril prospect at Temora including 150 m @ 0.31g/t Au and 0.21% Cu which included 60 m @ 0.5g/t Au and 0.26% Cu. Another intersection was 123 m @ 0.19g/t Au and 0.16% Cu including 42 m @ 0.25g/t Au and 0.18% Cu.

### QUEENSLAND

- Universal Resources Ltd reported that drilling by Xstrata Copper at Cabbage Tree Creek, immediately north of the Little Eva deposit (Roseby project), intersected copper-gold mineralisation beneath thick cover of younger rocks. The discovery hole returned 14m @ 2.00% Cu and 0.46g/t Au from 393 m including 6 m @ 3.19% Cu and 0.81g/t Au from 393 m. The same hole had 4m @ 0.66% Cu and 0.15g/t Au from 424 m and 14 m @ 1.30% Cu and 0.29g/t Au from 451 m.
- Malachite Resources NL reported encouraging copper grades from drilling at its Mount Lidster project between Mount Isa and Cloncurry. Two holes returned 6 m @ 4.19% Cu, 0.37g/t Au and 0.10% Co and 4 m @ 5.29% Cu, 0.23g/t Au and 0.07% Co respectively.
- Drilling by Ivanhoe Mines Ltd at the Amethyst Castle and Swan prospects, 100 km south of Cloncurry, yielded iron oxide copper gold (IOCG) type mineralisation and initial results from Swan included 79 m @ 1.45% Cu and 0.99g/t Au from 83 m, 115 m @ 0.965% Cu and 0.86g/t Au from 65 m, and 154 m of 0.81% Cu, and 0.49g/t Au from 115 m.

### SOUTH AUSTRALIA

- Oxiana Ltd released initial results from near-mine drilling at Prominent Hill which highlights potential for increased resources. Copper-gold and gold-only mineralisation was intersected 400–500 m beneath the current resource and mineralisation is open at depth. Better copper-gold intersections from chalcocite and bornite mineralised hematite breccias include 28 m @ 2.1% Cu and 0.6g/t Au, 17 m @ 1.8% Cu and 0.6g/t Au and 135 m @ 1.5% Cu and 1.0g/t Au. Wide intervals of 1–2g/t Au-only mineralisation occur in, and peripheral to, the copper-gold system.



- Hillgrove Resources Ltd continued drilling at its Kanmantoo project and holes adjacent to the Kanmantoo open pit yielded, from the North East zone, 37 m @ 1.77% Cu and 0.21g/t Au; from the Eastern Zone 25 m @ 1.52% Cu and 0.14g/t Au and from the South East Zone 25 m @ 1.52% Cu and 0.13g/t Au.

## WESTERN AUSTRALIA

- Significant drill intersections continued to be returned at Batavia Mining Ltd's Deflector deposit at Gullewa. Intersections included 5 m @ 43.53g/t Au and 2.1% Cu, 1.34 m @ 25.74g/t Au and 2.1% Cu and 12.13 m @ 5.70g/t Au and 0.5% Cu (all downhole depths). The total resource at Deflector is 2.65 Mt @ 6.04g/t Au and 1.23% Cu.
- Copper-gold mineralisation was reported by Crescent Gold Ltd adjacent to the Admiral Hill gold prospect near Laverton. Results included 41 m @ 0.6% Cu, 0.7g/t Au and 5.9g/t Ag which included 3 m @ 4.5% Cu, 4.2g/t Au and 59.9g/t Ag and 25 m @ 0.5% Cu, 0.1g/t Au and 0.6g/t Ag, including 3 m @ 1.8% Cu, 0.1g/t Au and 0.1g/t Ag.

## Production

Australian gold production reported by ABARE for 2006 was 245 t, a reduction of 18 t on the level they reported for 2005. The Super Pit at Kalgoorlie in Western Australia was again the largest producer with an output of almost 0.68 Mozs (21 t) but it was followed closely by the Telfer mine, also in Western Australia, which produced 0.66 Mozs (20.5 t). In 2006 Western Australia dominated Australian production with 165 t, just over two-thirds of total Australian output (Table 2).

**Table 2. Australian gold production 2002 to 2006.**

	2002 (t)	2003 (t)	2004 (t)	2005 (t)	2006 (t)
New South Wales	23.48	27.49	29.14	29	28
Victoria	3.24	3.11	3.46	6	6
Queensland	25.06	26.24	23.16	23	21
South Australia	3.14	5.33	5.12	6	7
Western Australia	187.20	189.07	164.32	173	165
Tasmania	6.05	9.31	10.60	8	5
Northern Territory	17.95	22.85	22.27	18	13
Australia	266.14	283.39	258.07	263	245

Source: ABARE Australian Commodity Statistics 2005 and ABARE Australian Mineral Statistic December Quarter 2006

ABARE's longer-term outlook is for gold production to rise to 335 t in 2009–10. The outlook for future production is reliant on new mines coming on stream successfully at expected levels of output especially the proposed Boddington (WA) and Prominent Hill (SA) operations and planned expansions at existing operations being realised.

## World Ranking

The USGS estimate of world gold reserves of 42,000 t was similar to 2005. According to the USGS, South Africa still has the world's largest reserve of gold at 6,000 t (14.3% a similar level as in 2005). According to the USGS Australia has the second largest reserve with approximately 12% of the world's holdings.

World mine production in 2006 fell by about 3% to 2,415 t with South Africa remaining the leading producer with about 275 t produced. The USA regained second ranking with an output of approximately 253 t. Australia was the world's third largest producer with 245 t but was closely followed by China with approximately 240 t.



Kalgoorlie Super Pit, Western Australia (Kalgoorlie Consolidated Gold Mines Ltd)

### Industry Developments

- A decision was taken to develop the Boddington project, south of Perth, Western Australia, by Newmont Mining Corp and AngloGold Ashanti Ltd at a cost of \$1.8–\$2.0 billion. Boddington has reserves of over 11 Mozs Au. Initial production is expected in late 2008 or early 2009. The project has an estimated mine life of more than 15 years and over the first five years gold output will average about 1Mozs Au/year. Subsequent production will be around 0.85 Mozs Au/year. Life of mine copper output will be about 30,000 t Cu/year.
- Oxiana Ltd announced in August that it would proceed with the development of a mine at its Prominent Hill deposit in the Gawler Craton, South Australia. Prominent Hill has resources of 118.7 Mt @ 1.3% Cu and 0.5g/t Au in the copper-gold breccia and 22.5 Mt @ 1.24g/t Au in the Eastern gold only zone. Planned output from the operation is 104,000 tpa of copper over the first four full years of operation and 71,000 tpa over the next six years and 115,000 ozs of gold per year over the life of the mine. The pre-production capital cost is expected by the Company to be \$775 million. The deposit remains open at depth and to the east and west and exploration is continuing.
- In Western Australia's area of the Tanami region, Tanami Gold NL poured the first gold from its Coyote mine in August. Annual production over an anticipated four-year mine life is 50,000 ozs.
- Citigold Corporation Ltd reported that it poured the first gold from its Warrior mine at Charters Towers, Queensland, in November. Development of the Warrior mine is continuing and annual production is expected to rise to 40,000 ozs.
- Production commenced at the Toms Gully mine, Northern Territory, with milling of ore and the first gold pour taking place in July. Annual production is expected to be around 45,000 ozs over a five year mine life but upgraded resource estimates to over 0.5 Mozs may extend its life.
- Range River Gold Ltd commenced production from the Withnell East and Withnell South pits at the Indee project, 80km SE of Port Hedland, Western Australia. The first gold pour from the project took place in August and stage 1 production is expected to be around 64,000 ozs per year over two years.

- GBS Gold International Inc announced that it had decided to commence production in late-2006 from the Union Reefs project, near Pine Creek, Northern Territory. Anticipated production is 150,000 ozs in 2007 rising to an annual rate of 250,000 ozs from 2008. Mining of ore will be from the Fountain Head and Rising Tide open cuts and the Brocks Creek underground mine. The first gold pour from the operation took place in September.
- Ballarat Goldfields completed stage one of the Ballarat East processing plant in December 2005. Mine development is continuing with over 5km of development completed. An extended mine design will focus on the recently discovered high grade mineralisation at depth around the Blue Whale Fault system. The extension of the mine will delay full gold production until 2009 and will cost an estimated A\$120 million.
- The first gold pour from the new Kangaroo Flat mine at Bendigo, Vic, took place in July and production of up to 90,000 ozs is expected by Bendigo Mining Ltd in 2006–07.
- Avoca Resources Ltd announced that it had arranged a \$15 million, one year financing facility to advance the development of its Trident gold project at Higginsville, Western Australia, and to provide working capital. Avoca is finalising a feasibility study into the development of Trident.
- Alkane Exploration Ltd's pre-feasibility study for the development of the Wyoming One and Wyoming Three deposits considered a 0.5 Mtpa open pit mine followed by 0.25 Mtpa underground operation to produce 30,000 to 35,000 ozs annually for six years. Total resources for the Wyoming deposits are 7.13 Mt @ 2.70g/t Au for 0.6 Mozs.
- The Directors of Crescent Gold Ltd approved the development of the \$15.4 million Laverton gold project, near Laverton, Western Australia. At full production the project is expected to yield 90,000 ozs per year over a 4.1 years mine life. A revised reserve estimate based on further drilling may increase the mine life.
- Dioro Exploration NL conducted a pre-feasibility study into underground mining at Frog's Leg in the Mungari East joint venture north west of Kalgoorlie, Western Australia, which returned positive results. The study indicated that 2.77 Mt @ 5.43g/t Au could be produced over 7.5 years, generating an operational surplus of up to \$158.5 million.
- Gleneagle Gold Ltd completed the refurbishment of the Fortnum project treatment plant mid-year and the first commercial gold production took place in July. At full production, annual output is expected to be around 55,000 ozs for an initial three years.
- Production started at Barra Resources Ltd's Burbanks project, 8 km south west of Coolgardie, Western Australia, in mid-year. Resources at the project at the start of production were 517,000 t @ 4.5g/t Au. Mining also started at Anglo Australian Resources NL's small Mandilla project 70 km south of Kalgoorlie, Western Australia, in June. The deposit has a probable reserve of 70,100 t @ 7.52g/t Au. Kalgoorlie-Boulder Resources Ltd mined the small Jackpot deposit 6 km east-north-east of Coolgardie. Ramelius Resources Ltd reported the first production of gold from its small Wattle Dam project in July.

## Iron Ore

Iron ores are rocks with high contents of minerals such as hematite ( $\text{Fe}_2\text{O}_3$ ) and magnetite ( $\text{Fe}_3\text{O}_4$ ), from which metallic iron (Fe) can be economically extracted. Iron ore is one of the raw materials used in blast furnaces to make pig iron. Pure iron is quite soft and is made stronger, harder or more elastic by adding small amounts of other elements such as manganese and nickel. These alloys of iron are used in construction, automobiles, trains and train tracks. Iron (in the form of steel) is the most useful metal known being used 20 times more than all other metals put together. About 98% of world iron ore production is used to make steel.

Rio Tinto and BHP Billiton operate a number of iron ore mines in the Pilbara region of north west Australia. These mines dominate the production of iron ore in Australia producing about

94% of total production (98% of total production is in Western Australia). Other locally significant operations include Koolyanobbing (WA), Cockatoo Island (WA), Talling Peak (WA), Jack Hills (WA), Koolanooka (WA), Middleback Ranges (SA), Savage River (Tas), Kara (Tas) and Tallawang (NSW). New mines are under construction at Cloud Break (WA), Hope Downs (WA), Koolan Island (WA) and Frances Creek (NT).

## Resources

In 2006, EDR increased by 13.2% to 18.6 Gt mainly due to the inclusion of Balmoral Southern and Mt Karara for the first time and large increases at the Balmoral Central (George Palmer), Christmas Creek and Cloud Break deposits. Western Australia has about 99% of Australia's EDR with about 89% occurring in the Pilbara district. Magnetite ore currently constitutes 24% or 4.4 Gt of Australia's EDR.

Paramarginal demonstrated resources remained unchanged at 0.2 Gt and subeconomic demonstrated resources also remained unchanged at 1.8 Gt. Inferred resources decreased by 4.8% to 17.9 Gt due decreases at Balmoral Central and Christmas Creek being offset by increases at Balmoral Southern, White Knight and Mt Karara. Western Australia has about 90% of Australia's total identified resources of iron ore with about 81% 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 and 30% of the Windarling resource which have both been quarantined for environmental reasons. The resource life of the accessible EDR of 18.5 Gt is over 65 years.

## JORC Reserves

About 42% of accessible EDR, or 7.8 Gt, is JORC Code reserves compliant. The resource life of accessible JORC Code reserves is over 25 years. Around 42% of EDR fell into the JORC Code reserves category.

## Exploration Expenditure

ABS data indicates that exploration expenditure for iron ore in 2006 totalled \$224.7 million an increase from \$152.2 million in 2005. About \$215.8 million or 96.0% was spent in Western Australia.

## Production

ABARE reported that Australia's iron ore production in 2006 was 275.1 Mt (261.4 Mt in 2005) with 98% produced in Western Australia. Exports in 2006 totalled 248.4 Mt (239.0 Mt in 2005) with a value of \$14 billion. ABARE has projected that Australia's iron ore production will increase from 264 Mt in 2005–06 to 441 Mt 2011–12. Exports are projected to rise from 239 Mt to 405 Mt over the same period.

## World Ranking

In 2006 Australia had about 11% of world EDR of iron ore and was ranked fifth after Ukraine (18%), Russia (15%), Brazil (14%) China (13%). In terms of contained iron, Australia has about 12% of the world's EDR and is ranked third behind Brazil (20%) and Russia (18%).

Australia produces around 16% of the world's iron ore production and is ranked third behind China (31%) and Brazil (18%).

## Industry Developments

### WESTERN AUSTRALIA

**Hamersley Iron** (100% Rio Tinto): The US\$290 million 15 Mtpa brownfields expansions at Mt Tom Price, Marandoo and Nammuldi were completed during 2006. At Yandicoogina construction continued on the US\$530 million expansion from 36 to 52 Mtpa. The new project called Junction South East (JSE) is expected to commence at the end of 2007 at a capacity of 16 Mtpa for about



16 years. The proposed Brockman Syncline 4 (BS4) project consists of three pits (West, Central and East Pits) that have a mine life of about 30 years. The project will have a nominal capacity of 20 Mtpa with a 35 km rail spur from the existing Brockman 2 infrastructure. Construction is planned to commence in 2007 with commissioning in 2009.

The US\$200 million rail duplication from Tunkawanna to Rosella Siding was completed in mid-2006. Construction commenced on the Phase 2 US\$690 million Port of Dampier expansion project in early 2006. The port capacity will be expanded from 116 to 140 Mtpa with completion due in late 2007.

**Robe River Associates** (53% Rio Tinto): The Mesa J operation will cease in 2010 with production declining from 2008. About 7 Mtpa of sub-grade material will continue to be processed in existing scrubber plants until 2015. The Mesa A and Warrambo deposits, 38 km north west of Mesa J, will be developed to replace the Mesa J operation. The new 25 Mtpa operation has a mine life of about 10 years. At West Angelas Robe River is considering expanding production from 25 to 35 Mtpa at a cost of \$217 million. In February 2007 Rio Tinto announced the US\$860 billion expansion of the Cape Lambert port from 55 to 80 Mtpa. When construction is completed in the fourth quarter of 2008 Rio Tinto's mine, rail and port capacity in the Pilbara will be capable of exporting 220 Mtpa. Rio Tinto will then have spent close to US\$5 billion since 2003 on infrastructure projects in the Pilbara.

**BHP Billiton:** The first ore from the US\$575 million Rapid Growth Project 2 (RGP2) was railed in May 2006 from Orebody 18. RGP2 has increased BHP Billiton's capacity by 8 Mtpa to 118 Mtpa, however, this will be offset by an 8 Mtpa reduction in capacity due to the suspension of the Goldsworthy shiploading operation while RGP3 is constructed. In 2006 the old Goldsworthy beneficiation plant and stockpiles were removed from Finucane Island and construction commenced on the new East Yard handling and loading infrastructure.

Construction of the US\$1.3 billion RGP3 which commenced in October 2005 continued throughout 2006. From late 2007 RGP3 is expected to increase BHP Billiton's capacity to 138 Mtpa. RGP3 includes development of "E" Deposit at Mining Area C to raise mine production from 22 to 42 Mtpa, an overland conveyor, new crushing and screening facilities and increased port and rail capacity. BHP Billiton is planning a US\$1.4 billion expansion (RPG4) of the Newman operations to take the total capacity to 152 Mtpa by 2010.

At Yandi development of the new Eastern 356 Pit from mid-2006 will replace the contribution by the Eastern 2 Pit which will be mined out by mid-2007. The first 12 months of work in Eastern 356 will remove the layer of waste on top of the deposit. Opening Eastern 356 will provide a short haul distance to the Yandi 1 processing plant.

**Portman Ltd:** In early 2006 the Koolyanobbing infrastructure for the upgrade to 8 Mtpa was completed and commissioned. Production from Windarling and Mt Jackson at Koolyanobbing became major sources of plant feed during 2006 and in 2007 additional mining equipment will further increase productive capacity. All process ore is transported by rail to the Port of Esperance, 578 km to the south. At Cockatoo Island, a feasibility study will precede a decision in mid-2007 to construct a third stage of the seawall to extend the life of the mine. Currently the operation is scheduled to close in late 2007.

**Mount Gibson Iron Ltd** (MGI): At Talling Peak production was increased from 2.3 to 3.0 Mtpa during 2006 with pits T3 and T4 now planned to be expanded into a single pit called T6 that will be more than 1.2 km long. There is a possibility of extending the mine life at Talling Peak with the development of an area to the north east described as T1. In mid-2006 MGI completed a desktop study into the feasibility of the Extension Hill Direct Shipping Ore project. MGI propose spend \$73 million to mine 3.0 Mtpa from early 2008. The ore would be trucked to Perenjori then railed 239 km to the port of Geraldton. The Definitive Feasibility Study is due to be completed in the first quarter of 2007. A Bankable Feasibility Study was completed in February 2006 on the Extension Hill magnetite project near Mount Gibson. MGI plan to establish a \$715 million mine that produces 5 Mtpa of magnetite concentrate (68% Fe) that will be transported to the port of Geraldton by a 280 km slurry pipeline. Sinom Investments Ltd exercised the right to purchase MGI's shareholding in Asia Iron Holdings Ltd the owner of the Extension Hill magnetite project.





The Koolan Island iron ore mine, Western Australia (Mount Gibson Iron Ltd)

**Aztec Resources Ltd:** (now owned by MGI) Construction of the \$147 million Koolan Island Iron Ore Project commenced at the end of June 2006. Mining commenced in the Eastern and Mullet Pits in late 2006 with shipments due to begin in the June quarter of 2007. Production will reach 4.0 Mtpa by 2008 and continue over a nine year life. In December 2006 MGI had acquired over 90% of Aztec's fully paid ordinary shares and expects compulsory acquisition of the remaining shares to be completed by end of February 2007.

**Hancock Prospecting:** The \$1.3 billion Hope Downs project will be operated by Rio Tinto with an initial production of 22 Mtpa (Stage 1) then expanding to 30 Mtpa (Stage 2). Construction commenced in May 2006 with first production expected in early 2008. The 58 km Lang Hancock railway will connect the mine to Rio Tinto's existing rail and port infrastructure. Hancock Prospecting is undertaking infill drilling at the Roy Hill deposit and expects to complete a detailed mine plan in 2007.

**Fortescue Mining Group Ltd (FMG):** In April 2006 FMG completed the mining feasibility study for the Cloud Break and Christmas Creek deposits. Earthworks commenced at the port site at Anderson Point in February 2006 and dredging commenced in July 2006 with completion due in May 2007. In June 2006, FMG entered into a long term mining alliance with Roche Mining known as the Pilbara Mining Alliance. Construction of the 255 km rail line commenced in November 2006 and is due for completion in December 2007 at a capacity of 70 Mtpa. Overburden removal is expected to commence in the third quarter of 2007 with ore mining commencing in the fourth quarter of 2007. The mining schedule provides for a production rate of 45 Mtpa to be achieved within the first 15 months of ore shipment. Shipments from the \$3.7 billion project are expected to commence in the first quarter of 2008.

**Murchison Metals Ltd:** The \$41 million Stage 1 Jack Hills project which commenced mining in September 2006 involves a 5 year mine plan with an initial production 1.5 Mtpa and increasing to 1.8 Mtpa in 2008. Murchison will mine hematite using contract mining, crushing and screening operations. Ore will then be transported 540 km to Geraldton using 30 prime movers and 90 trailers for shipment to customers in Asia. The first shipment of iron ore left Geraldton in February 2007. In March 2006 Murchison Metals announced the commencement of the Definitive Feasibility Study

(DFS) into the second stage of the Jack Hills project. Stage 2 involves the expansion of mining up to 25 Mtpa, construction of a 420 km rail line and development of a new deep water port at Oakajee near Geraldton. Murchison expects the DFS to be completed in the first quarter of 2007 and production to commence in 2010.

The Northern Infrastructure Feasibility Study, a Joint Venture between Murchison Metals and Midwest Corporation, completed a rail option assessment in December 2006. The study concluded that the \$530 million northern route is the only viable option for the railway from Jack Hills and Weld Range to Oakajee. During 2006 an international consortium comprising POSC, Mitsubishi and Toll entered into an agreement to present an infrastructure proposal to build, own and operate the new railway and port.

**Midwest Corporation Ltd:** The first shipment of iron ore fines from the Koolanooka/Blue Hills Direct Shipping Ore Project left the port of Geraldton in February 2006. The \$26 million project has a planned 1.0 Mtpa production rate over 7 years. In October 2006 Midwest announced the purchase of 64 rail wagons in preparation for the transition from road to rail transport from the Koolanooka mine in mid-2007. In 2006 planning commenced for the transition from removing the fines stockpile to hard rock mining at Koolanooka and Blue Hills. Drilling commenced at Koolanooka Detritals and Mungada East to support a planned expansion to 2.0 Mtpa after Berth 5 is commissioned at the Port of Geraldton at the end of 2007.

A Joint Venture with Sinosteel has approved \$30 million to undertake studies on the Weld Range hematite and the Koolanooka magnetite projects. The proposed \$800 million Weld Range project consists of a 15 to 20 Mtpa mine connected by a 394 km rail line to the Oakajee port near Geraldton. A Bankable Feasibility Study is planned to be completed in mid-2008 and project start-up is anticipated in 2010. The \$1.0 billion Koolanooka magnetite project, 160 km south east of Geraldton, is planned to produce 6.0 Mtpa of concentrate/pellets for at least 20 years. A Scoping Study was completed in February 2006 and production could commence as early as 2010.

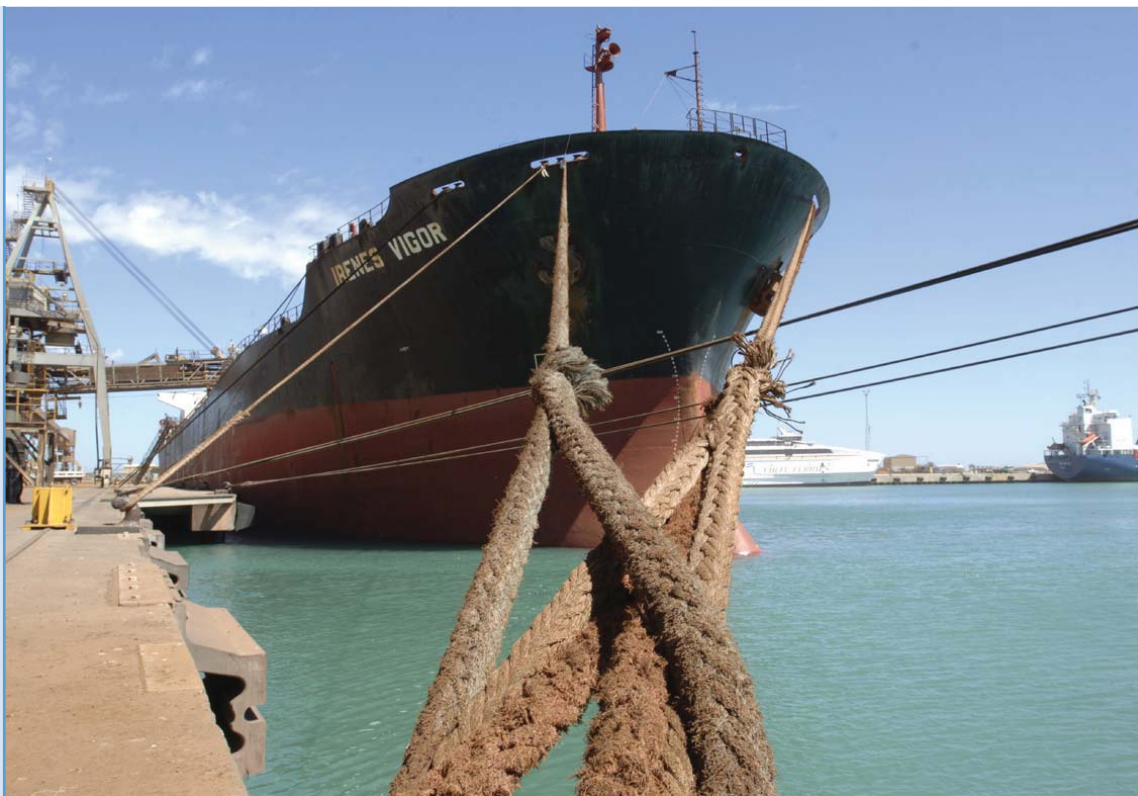
**Grange Resources Ltd:** A Bankable Feasibility Study on the US\$1.2 billion Southdown-Kemamam Project was completed in early 2006. Grange is planning to mine at a rate of 17.8 Mtpa to produce 6.6 Mtpa of magnetite concentrate grading 69% Fe. The concentrate will be pumped 105 km via a slurry pipeline to the Port of Albany for export to a pellet plant located in Kemamam, Malaysia. Project construction is expected to commence in late 2007 with first pellet production planned for early 2010. In March 2006 Grange launched a tender process for joint venture partners for the project.

**Gindalbie Gold Ltd:** In April 2006 Gindalbie signed a Joint Venture agreement with Anshan Iron and Steel Group Corporation (AnSteel) of China for the development of the Karara Iron Ore project located 260 km east of Geraldton. Stage 1 consists of mining hematite at an initial rate of 2.0 Mtpa from early 2008 rising to 4.0 Mtpa from 2010. Ore would be trucked 85 km to the Morawa rail siding then railed 200 km to Geraldton for export. The Stage 2 Feasibility Study is expected to be completed in February 2007 with production due to start in 2010. The \$1.0 billion Stage 2 project involves mining 20 Mtpa of magnetite to produce 8 Mtpa of concentrate which would be transported via a 225 km slurry pipeline to the port of Geraldton. The Karara Joint Venture partners plan to export the concentrate from Geraldton with 4.0 Mtpa to be shipped to the port of Yingkou in China to be pelletised at a jointly owned plant.

**Consolidated Minerals Ltd:** At Mindy Mindy, 60 km north west of Newman, a 5 Mtpa mine costing up to \$50 million is under investigation. The Mindy Mindy project is under a joint venture arrangement with Fortescue Metals Group Ltd, with Fortescue holding a 50% interest in the project. The Joint Venture will have access to the rail and port infrastructure developed by Fortescue in the East Pilbara region.

**Resource Mining Corporation (RMC):** Propose to mine 1.5 to 2.0 Mtpa of direct shipping ore at the \$50 million Argyle Iron Ore Project and truck the product 170 km to Wyndham for export. RMC is undertaking a pre-feasibility study that includes evaluating shipping options through the port of Wyndham. In early 2006 RMC announced a JORC compliant inferred resource of 17 Mt at 55% Fe





Loading iron ore at the Port of Geraldton, Western Australia (Midwest Corporation Ltd)

for the Argyle deposit with an average 0.5:1 waste to ore ratio. RMC is seeking an equity partner to assist in the development of the Argyle deposit.

**Cape Lambert Iron Ore Ltd:** The Cape Lambert magnetite deposit is only 5 km from the coast near Karratha and has an average waste to ore ratio of 0.6:1. The company proposes to construct an operation producing 5 Mtpa of concentrate costing \$600 million with no pellet plant. In 2006 the company commenced a Bankable Feasibility Study that is expected to be completed by mid-2007 with production planned to start in late 2009.

**Atlas Iron Ltd:** At the Pardoo Iron Ore project 75 km east of Port Hedland Atlas plans to commence a 1.0 Mtpa direct shipping operation in March 2008 rising to 3.0 Mtpa by 2010. The ore will be trucked to Port Hedland for export from the common user berth. Atlas completed a pre-feasibility study in January 2007 which stated that a 1.0 Mtpa operation will cost \$8.3 million with an additional cost of \$13 million to upgrade to 3.0 Mtpa. Atlas plan to have a Definitive Feasibility Study completed in June 2007 with construction commencing in the September.

**CITIC Pacific Ltd:** In July 2006, CITIC paid Mineralogy Pty Ltd US\$215 million for the right to mine 1 billion tonnes of magnetite from the Balmoral Central deposit. CITIC also agreed to purchase a further 1 billion tonnes for US\$200 million subject to confirmatory drilling. An initial US\$1.37 billion is planned to be spent on a 12 Mtpa mine that is expected to be in production by 2009. Included in the development is a pellet plant and port at Cape Preston. A US\$1.1 billion second stage is also proposed.

**Australasian Resources Ltd (ARL)** (formerly Sherlock Bay Nickel Corporation Ltd): Mineralogy Pty Ltd granted ARL the right to mine 1 billion tonnes of magnetite from the Southern Block at the Balmoral deposit located 80 km south west of Dampier. ARL plan to develop a US\$2.1 billion 42 Mtpa mine to produce exports of 5.2 Mtpa of concentrate, 4.9 Mtpa of pellets and 1.45 Mtpa of HBI briquettes. The mine would be 30 km from Cape Preston where ARL and CITIC would share port facilities including pro-rata costs.

**Golden West Resources Ltd:** Propose to develop the Wiluna Iron Project located 40 km west of the township of Wiluna. Stage 1 consists of producing 0.5 to 1.0 Mtpa of direct shipping grade hematite by late 2007 using existing infrastructure. Ore would be mined and trucked to Leonora for rail to Port of Esperance where construction of a storage shed is due to commence in mid-2007. Stage 2 consists of the development of a 10 to 12 Mtpa mine with exports via either Oakajee or Esperance (both require a 300 km rail line to be constructed). Stage 1 would provide the cash flow to support the development of Stage 2.

**Ferrowest Ltd:** Plan to develop the \$389 million Yalgoo iron ore project 230 km east-north-east of Geraldton. The 2.4 Mtpa Yogi open-pit mine would produce 770,000 tpa of magnetite concentrate at +65% Fe. Ferrowest plan to feed a pig iron plant at the mine site to produce 0.5 Mtpa of +96% Fe ingots for export through the Port of Geraldton. A scoping study was completed in December 2006 and a pre-feasibility study is expected to be completed in June 2007.

**Jupiter Mines Ltd:** Plan to produce 1.0 Mtpa of Direct Shipping Ore by end 2007 from the Central Yilgarn Iron Ore project that includes the Mt Mason deposit located 112 km north west of Menzies. The \$31 million project proposes to truck ore to Menzies then transport the ore by rail to Esperance.

**Aurox Resources Ltd:** At Balla Balla, located about 90 km east of Karratha, Aurox plan to construct a \$155 million concentration plant to produce 2.0 Mtpa of a vanadium rich titanomagnetite concentrate. A proposed second stage involves constructing a \$290 million vanadium recovery plant. Aurox expect the project to be operational in 2009 and to have a mine life of at least 30 years.

**Port of Geraldton:** The new \$35 million shiploader at Berth 5 is scheduled to be commissioned in the fourth quarter of 2007 with a capacity of up to 10 Mtpa. The total investment in port infrastructure over the last 3 years has been some \$235 million. The Geraldton Iron Ore Alliance is proposing a \$1.6 billion rail network capable of handling 100 Mtpa and a port at Oakajee, 20 km north of Geraldton, with a capacity of 140 Mtpa to be constructed by 2010. Previous work on the Oakajee port development could save up to 24 months in the planning and approval processes. Another group, Yilgarn Infrastructure Ltd, also plan to construct third party access to rail and port infrastructure for existing and potential iron ore producers in the Mid-West Region. The plan includes a deepwater port at Oakajee and a rail network to projects such as Jack Hills and Weld Range.

**Port Hedland Port Authority:** A \$200 million expansion of public shipping facilities is scheduled to be commissioned with a capacity of up to 15 Mtpa late in 2008. The Pilbara Port Study conducted by Worley Parsons for the Western Australian Government has identified Ronsard Island, 80 km west of Port Hedland, as the preferred site for any new iron ore port in the Pilbara.

#### SOUTH AUSTRALIA, TASMANIA, NORTHERN TERRITORY AND QUEENSLAND

**OneSteel Ltd:** At Whyalla in South Australia the hematite export facilities were successfully commissioned in October and November 2006. This included a rail upgrade, new rail wagons, a rilling tipping facility and an export shed with the three trans-shipping vessels due to be commissioned in first quarter of 2007. OneSteel plan to export 3.0 Mtpa of hematite ore over approximately 10 years. The remainder of the \$325 million Project Magnet is planned to be commissioned in 2007–08 and includes a mine cut back, a new magnetite concentrator and 62 km slurry pipeline and upgrading a pellet plant. Project Magnet extends the life of the Whyalla steelworks from 2020 to 2027 and lowers the cost of steel production.

**Western Plains Resources Ltd (WPG):** Intends to develop the Peculiar Knob hematite deposit located 80 km south east of Coober Pedy in South Australia as a direct shipping ore mine at a rate of up to 2.0 Mtpa from 2008. In December 2006 WPG started a \$1.6 million feasibility study which includes infill drilling and is due to be completed by June 2007. A drilling program is planned at the nearby Hawks Nest deposits to outline additional hematite resources. WPG also plans to investigate the Hawks Nest magnetite deposits for the production of magnetite concentrate, pellets or pig iron.

**Goldstream Mining NL:** Successfully completed a scoping study on the Cairn Hill project 55 km south east of Coober Pedy in South Australia. A feasibility study has commenced to evaluate two options:

- i) To produce up to 1.0 Mtpa of magnetite and up to 35,000 tpa of a gold/copper concentrate, or
- ii) Export 2.8 Mtpa of ore to China for processing over a 10 year open-pit mine life. The study is expected to be completed in second quarter of 2007.

**Centrex Metals Ltd:** The Wilgerup hematite resource located 30 km south east of Lock in South Australia is being evaluated to produce 1.0 Mtpa over 5 years commencing in 2008. A drilling program commenced in September 2006 to provide JORC compliant resources at Wilgerup and enable a feasibility study for mine development.

**Stemcor Holdings Ltd:** The mine life at Savage River in Tasmania has been extended to May 2009 through the development of the Centre Pit South. A feasibility study is being conducted into increasing the life of the Savage River mine by extending the North Pit. In 2006 a \$26 million remediation project was funded by the State government for the Savage River mine including \$7 million for remediation of the B Dump complex (the major pollution source on the site) that will be completed in 2007–08.

**Gujarat NRE Resources NL** (formerly Zelos Resources NL): A desktop study of the Nelson Bay River project in north west Tasmania found that a \$20 million 100,000 tpa open-pit magnetite mine could operate over 10 years. In January 2007 Zelos announced an inferred resource of 6.9 Mt at 38.2% Fe and plans to continue a drilling program in 2007.

**Territory Iron Ltd:** The \$10 million Frances Creek project located 180 km south of Darwin and 15 km from the new Alice Springs-Darwin railway was given board approval in February 2006. Mining at a rate of 1.0 Mtpa is scheduled to begin in March 2007 rising to 1.5 Mtpa in 2008. FreightLink expect a start-up date for railing of iron ore will be July 2007 with the first shipment expected in August 2007. The mine is being reopened after a 33 year closure that was caused by cyclone Tracy. A new bulk ship loader at the Port of Darwin is scheduled to be completed in the first quarter of 2007.

**Curtain Bros (Qld) Pty Ltd:** An open-pit iron ore mine is proposed at Mt Moss 105 km west-north-west of Townsville, Queensland.

## IRON AND STEEL

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

- Steel is produced at Port Kembla, Whyalla, Rooty Hill, Mayfield and Laverton North.
- Demolition of the \$2.6 billion Boodarie hot briquetted iron plant at Port Hedland commenced in 2006 and is expected to be completed in 2008.
- The Hismelt DRI processing plant at Kwinana made the first shipment of 40,000 t of pig iron to customers in the USA in the second quarter of 2006. The plant will be ramped up to the design capacity of 0.8 ktpa by 2008.
- **Mount Gibson Iron Ltd:** Undertaking a feasibility study into the construction of up to four 500,000 tpa iron making plant 25 km west of Mingenew, Western Australia. MGI plan to use the Midrex rotary hearth furnace technology, magnetite from Koolanooka South and coal from near Mingenew.
- **Ferrowest Ltd:** Pre-feasibility study expected in June 2007 for a 0.5 Mtpa iron making project located at Yalgoo, east of Geraldton, Western Australia.
- **Boulder Steel Ltd:** Plan to build a US\$450 million steel mill and seamless tube mill at Swanbank near Ipswich, Queensland. Production is targeted to begin in 2009–10 subject to a construction start in the first half of 2007. The mill is designed to recycle scrap metal and has a capacity to produce up to 400,000 t of seamless steel tubing a year.
- **Australasian Resources Ltd:** Plan to develop a HBI plant with a capacity of 1.45 Mtpa at Cape Preston, Western Australia.



## Lithium

Lithium (Li) is recovered from the mineral spodumene ( $\text{Li}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2$ ) and lithium-rich brines. It is used in a range of products such as ceramics, glass, batteries and pharmaceuticals. Lithium use in rechargeable batteries has expanded significantly in recent years due to increasing use in portable electronic devices.

Lithium produced from the Sons of Gwalia Ltd's Greenbushes mine in south west Western Australia has been used in the production of specialty glasses, glass bottles, ceramics and ceramic glazes. Its ore also is a feedstock for the production of lithium carbonate in the chemical industry.

### Resources

All of Australia's lithium resources are in the Greenbushes spodumene deposit in Western Australia. It is the world's largest and highest grade spodumene deposit and accounts for all EDR in Australia. EDR in 2006 remains unchanged at 170,000 t of lithium. All of lithium EDR is accessible for mining. Approximately 85% of AEDR comprises JORC Code ore reserves as reported by industry.

### Exploration

There are no statistics available on exploration expenditure for lithium. With continuing world oversupply of lithium, particularly in the form of lithium-rich brines, notably from Chile, substantial exploration expenditure in Australia is considered unlikely in the near future.

### Production

Chile was the largest producer of lithium in 2006, followed by China. The supply of lithium carbonate from brine operations in Chile and Argentina, along with increased production in China, is continuing to impact negatively on the price and supply of lithium on the world markets.

Although Sons of Gwalia Ltd has been in administration since September 2004, the Greenbushes lithium production continues at full capacity. In 2006, the Greenbushes operation produced 222,101 t of spodumene concentrate, which contains 4 to 7.5%  $\text{LiO}_2$ .

### World Resources

Based on world estimates published by the USGS for 2006, Chile holds approximately 73% of the world's lithium resources followed by China with 13%, Brazil with 4.6% and Canada with just over 4%. Resource data are not available for some important producing countries including Argentina and Russia.

Lithium resources occur in two distinct categories, lithium minerals and lithium-rich brines. Lithium brine resources, which is the dominant feedstock for lithium carbonate production, are produced dominantly by Chile. However, Canada, China and Australia have the most significant resources of lithium minerals.

World production in 2006 was estimated by USGS to be 21,100 t of contained lithium. However, information excludes USA production for commercial reasons. Based on USGS data, Chile with 39% remained the world's largest producer, followed by China with 14% and Russia on 10%.

### Industry Developments

There were no major developments in Australia's lithium industry in 2006.

## 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 remained unchanged at 344 Mt in 2006. South Australia has the largest holding of EDR with a global resource of 579 Mt of magnesite. About 235 Mt of this resource is classified as EDR, unchanged from 2005.

Queensland has the second largest inventory of magnesite EDR. The bulk of this occurs at Kunwarara (70 km north west of Rockhampton), where Queensland Magnesite Pty Ltd has global resources 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 26 Mt. Magnesite in the deposit typically grades 42.8% MgO and is part of a much larger global resource of 195 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 north west of Young, NSW), and at Bandalup (20 km east of Ravensthorpe, WA)

Subeconomic demonstrated resources of 57 Mt of magnesite remained unchanged from 2005. All of these resources occur in Queensland and Tasmania.

Inferred resources remained steady at 931 Mt with Queensland accounting for 50% of these resources followed by South Australia (31%) and Tasmania (16%).

## Accessible EDR

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 2006 rate of production, magnesite resources in the JORC Code reserves categories are adequate for 84 years.

## Exploration

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

## Production

In 2005–06, Queensland Magnesite Pty Ltd produced 446,752 t of magnesite. The company supplies high grade electrofused and deadburned magnesia to the global refractory market, and is expanding calcined magnesia production for a wide range of applications. USGS data indicate that Russia (30%), North Korea (20%) and China (17%) were the largest producers of magnesite in 2006.

## 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. The Kunwarara deposit is the world's largest known resource of cryptocrystalline, nodular magnesite, a high quality ore.

## Industry Developments

There were no major developments in Australia's magnesite industry in 2006.



Bootu Creek manganese ore mine, Northern Territory (OM Holdings Ltd)

## Manganese Ore

Manganese occurs in nature mainly as pyrolusite ( $\text{MnO}_2$ ) and to a lesser extent as rhodochrosite ( $\text{MnCO}_3$ ). Manganese is an important alloying agent. In steel production, manganese improves rolling and forging qualities as well as strength, toughness, wear resistance and hardness. In steel manganese has no satisfactory substitute due to its low price and ability to desulphurise and prevent oxidation. Manganese is also used in dry cell batteries (Electrolytic Manganese Dioxide), in plant fertilisers and animal feed and as a colorant (for example, manganese can produce an amethyst colour in glass). About 90% of all manganese consumed annually goes into steel as an alloying element and manganese is the fourth most used metal after iron, aluminium and copper.

In Australia there are three operating manganese mines, namely Groote Eylandt (NT), Bootu Creek (NT) and Woodie Woodie (WA). Mineral Resources Ltd reprocesses manganese tailings near the Woodie Woodie operation. Manganese concentrate processing plants are located at Bell Bay (Tas) and at Newcastle (NSW).

### Resources

In 2006 Australia's EDR of manganese ore decreased by 2.6% to 139 Mt with increases in EDR at Woodie Woodie and Bootu Creek being offset by a decrease in EDR at Groote Eylandt. Paramarginal demonstrated resources remained unchanged at 23 Mt and subeconomic demonstrated resources also remained unchanged at 167 Mt. Inferred resources increased 3.1% to 160 Mt due to increases at Groote Eylandt and Woodie Woodie.

### Accessible EDR

All manganese ore EDR (139 Mt) is accessible. The resource life is about 15 years at current rates of production of beneficiated manganese ore.

## JORC Reserves

Manganese ore JORC Code reserves are 112 Mt (80% of accessible EDR). The resource life based on JORC Code reserves and at the current rate of production of beneficiated manganese ore is about 12 years.

## Exploration Expenditure

Data relating to exploration expenditure for manganese are not published by ABS on either a State or National basis. Consolidated Minerals Ltd spent \$6.0 million on exploration during 2006 which lead to a new discovery at Topvar and extensions below the Rhodes pit.

## Production

ABARE reported that Australia produced 4.6 Mt of beneficiated manganese ore in 2006 (3.9 Mt 2005). Exports for 2006 totalled 4.2 Mt (2.9 Mt 2005) valued at \$463 million (\$468 million 2005)

## World Ranking

Australia has 12% of the worlds EDR of manganese ore and is ranked fourth behind Ukraine (34%), India (21%) and China (17%). In terms of contained manganese Australia has 15% of the worlds EDR and is ranked third behind Ukraine (33%) and India (22%).

Australia produces 14% of the world's manganese ore and is ranked third behind China (19%) and South Africa (15%).

## Industry Developments

**GEMCO:** In September 2006, GEMCO and the Anindilyakumwa Land Council signed an historic agreement to secure ongoing mining operations on Groote Eylandt. GEMCO has agreed to continue employment of Anindilyakwa people, commit to environmental regulations including rehabilitation and give a financial boost to the Aboriginal community. The company proposes to spend US\$150 million to eliminate bottlenecks in the processing plant and this will increase capacity from 3.1 to 4.1 Mtpa and reduce operating costs from 2008.

**OM Holdings Ltd:** At Bootu Creek, located 110 km north of Tennant Creek, the first shipment of beneficiated manganese product left Darwin Harbour in June 2006 bound for China. During 2006 pit optimisations studies were undertaken on the Shekuma deposit and from late 2006 the mine plan was changed to allow for the minimizing of waste stripping and the mining of shallow pits around the Shekuma deposit. This will provide at least 12 months of sustainable production at lower costs. Processing plant rectification work to improve performance was completed in October 2006. OM Holdings plan to expand production from 0.55 to 1.0 Mtpa at an incremental cost of \$10 million. This expansion will depend on market conditions, an expanded resource base and the results of a feasibility study.

**Consolidated Minerals Ltd:** The Woodie Woodie operation, located 400 km south east of Port Hedland, now has a plant capacity of 1.1 Mtpa following an expansion that was completed in 2005. In late 2006, a new 120 t excavator was commissioned to improve the efficiency of the mining fleet. Consolidated Minerals is continuing an intensive exploration program in the Woodie Woodie region for mine life extensions.

**Mineral Resources Ltd:** During 2006 Process Minerals International Pty Ltd (PMI is a subsidiary of Mineral Resources Ltd) completed the development of a three stage beneficiation plant that treats fine manganese tailings (-1.2 mm) from the Woodie Woodie processing plant. The plant has the capacity to produce in excess of 320,000 tpa of a 44% manganese concentrate. PMI made an initial shipment of a trial high grade fines product in March 2006. In February 2007, PMI signed a sales contract with CITIC Dameng Industries Ltd of China for the annual sale of 280,000 t of high grade manganese fines.

## Mineral Sands

The principal components of mineral sands are rutile ( $\text{TiO}_2$ ), ilmenite ( $\text{FeTiO}_3$ ) and zircon ( $\text{ZrSiO}_4$ ). Rutile and ilmenite are used principally in the production of titanium dioxide pigment. Less than 4% of total titanium mineral production, typically rutile, is used in making titanium sponge metal. Zircon is used as an opacifier for glazes on ceramic tiles, in refractories and for foundry industry. Recently there has been some interest in monazite as a source for thorium for possible use in thorium nuclear reactors for electricity generation.

### Resources

EDR of ilmenite increased by 1.7% to 218.5 Mt in 2006, up from 214.9 Mt in 2005.

About 59% of Australia's EDR of ilmenite is in Western Australia, 26% in Queensland with the remainder in New South Wales (6.3%), Victoria (5.6%) and South Australia (2.9%). A small quantity of ilmenite EDR, 113,530 t has been reported for the Northern Territory in 2006.

EDR of rutile, which includes leucoxene in Western Australia, increased marginally by 5.9% from 20.5 Mt in 2005 to 21.7 Mt in 2006. Queensland has the largest share of Australia's rutile EDR with 31.8% followed by New South Wales (26.1%), Western Australia (20.4%), Victoria (18.2%) and South Australia (3.2%). The Northern Territory has about 56,000 t of rutile.

EDR of zircon increased by 3% from 32.9 Mt in 2005 to 33.9 Mt in 2006 with Western Australia (36.9%) and Queensland (28%) accounting for most of Australia's zircon EDR. The balance was in South Australia (16%), New South Wales (10.5%), and Victoria (8.2%).

Australia's subeconomic demonstrated resources of ilmenite, rutile and zircon in 2006 amounted to 48.8 Mt of ilmenite, which was a reduction of 10.1% on 2005, 13.7 Mt of rutile, an increase of 5.4% on previous year, and 19.9 Mt of zircon, a decrease of 1.5% on 2005.

Inferred resources of ilmenite increased by 10 Mt in 2006 to 126 Mt. Victoria has the largest proportion of inferred ilmenite resources with 39.8% of the Australian total followed by New South Wales (25.9%), Western Australia (15%) and Queensland (14.7%).

Inferred resources of rutile decreased by 1 Mt in 2006 to 28 Mt. Victoria has the largest share of Australia's inferred rutile resources with 46.3% of the Australian total followed by New South Wales (39.6%) South Australia (6.5%), Western Australia (4.9%) and Queensland (2.7%).

Inferred resources of zircon remained unchanged at 30 Mt. Victoria is the main holder of zircon inferred resources with 50.6% of the Australian total, followed by New South Wales (25.7%), Western Australia (10.6%) and South Australia (7.3%).

### Accessible EDR

A significant portion of mineral sands EDR is in areas quarantined from mining, which are largely incorporated into national parks. Geoscience Australia estimates that some 17% of ilmenite, 26% of rutile and 24% of zircon EDR is unavailable for mining. Deposits in this category include Moreton Island, Bribie Island and Fraser Island; Cooloola sand mass; Byfield sand mass and Shoalwater Bay area, all in Queensland, and Yuraygir, Bundjalung, Hat Head and Myall Lakes National Parks in New South Wales.

### JORC Reserves

Approximately 23% of ilmenite, 26% rutile and 21% zircon of accessible EDR (AEDR) comprise JORC Code reserve. The remaining AEDR 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 2006 rate of production, AEDR of ilmenite, rutile and zircon is sufficient for an average of 76, 67 and 52 years respectively. However, resources in the JORC Code reserves categories are adequate for only 17 years for ilmenite, 18 years for rutile, and 11 years for zircon.

## Exploration

According to quarterly ABS figures, expenditure on exploration for mineral sands in 2006 was estimated at \$31.3 million compared with \$30.1million in 2005.

## Production

In 2006, Australia produced 2.4 Mt of ilmenite, 232,000 t of rutile, 133,000 t of leucoxene and 492,000 t of zircon (compared with 2.03 Mt of ilmenite, 177,000 t of rutile, 55,000 t of leucoxene and 426,000 t of zircon in 2005). The bulk of Australia's rutile (231,000 t) and zircon (487,000 t) production were exported compared to about 905,000 t of ilmenite production. The remaining ilmenite is upgraded to synthetic rutile containing about 92-94% TiO<sub>2</sub>. In 2006, Australia produced 703,000 t of synthetic rutile (compared with 752,000 t in 2005).

## World Ranking

According to Geoscience Australia and USGS data, Australia has the world's largest EDR of rutile and zircon with 39%, and 43%, respectively and has the second largest share of the world's ilmenite with 19% behind China which has 34%. Other major country rankings include India (14%), South Africa (11%) and Norway (6%) for ilmenite; South Africa (15%) and India (13%) for rutile; and South Africa (28%) and Ukraine (8%) for zircon.

In 2006, world production of ilmenite increased by 5% to 9.47 Mt, rutile increased by 35% to 506,000 t, and zircon decreased by 14% to 930,000 t. Australia is the largest producer of rutile with about 46% of the world production followed by South Africa with 21% and Sierra Leone with 16%. It is the largest producer of ilmenite with 25% followed by South Africa with 18% of the world's production and also the largest producer of zircon with 53% with South Africa second at 33%.

## Industry Developments

Companies which produced heavy mineral sands during 2006 were Iluka Resources Ltd, BeMax Resources Ltd, TiWest joint venture, and Doral Mineral Sands Pty Ltd, all in Western Australia and Consolidated Rutile Ltd in Queensland. Iluka and BeMax also produced heavy minerals in the Murray Basin in Victoria and New South Wales respectively. Production commenced from Matilda Minerals Andranangoo deposit on Tiwi Islands in Northern Territory and construction is underway on the Mindarie heavy minerals project, held by Australian Zircon NL, in South Australia.

Iluka Resources Ltd heavy mineral sand operations in Western Australia are located in two regions. The Mid-West region north of Perth comprises the main mines of Eneabba (two wet concentrators, five mining units) and Gingin (wet concentrator, one mining unit). The Narngulu facility at Geraldton includes mineral separation, zircon finishing and synthetic rutile plants and port operations and storage facilities at Geraldton. The company is drilling and re-evaluating the Cataby deposit, including bulk sampling to increase and upgrade the resource. Production of heavy mineral sand commodities from Mid-West region in 2006 amounted to 90,000 t of rutile, 218,000 t of synthetic rutile, 578,000 t of ilmenite, 245,000 t of zircon.

Iluka's South-West region, south of Perth, is based on mines at Yoganup Extended, Yoganup West and Wagerup (wet concentrator and mining unit at each site). The Waroona mine was under construction with mining to start in first quarter of 2007. Yoganup Extended mining was to cease in early 2007 with wet concentrator relocated to Waroona. Yoganup West was also to close in 2007 and Cloverdale to commence mining in 2007. Production in the Iluka's South-West region amounted to 289,000 t of synthetic rutile, 677,000 t of ilmenite and 65,000 t of zircon. About 24,000 t of Hyti 70/91 also was produced in this region.

Iluka Resources Ltd's Douglas project in Victoria is based on the resources of three main deposits comprising the Bondi Main, Bondi West and Bondi East. The infrastructure includes a single mining unit plant, a wet concentrator plant, and a mineral separation plant located at Hamilton to produce the final specification rutile and zircon. The commissioning of the mineral separation plant commenced in November 2006 with completion anticipated in February 2007. Ramp up to full production was expected in first half of 2007 and estimated 2007 production was 110,000 t zircon and 70,000 t rutile. Initially, ilmenite produced will be returned to the mine.

In addition to the Douglas project, the company has a group of deposits at Ouyen in north west Victoria comprising Kulwin, Woornack, Rownack, Rainlover, and Pirro, and another group at Euston in New South Wales named Castaway, Kerribee, Earl, Dispersion and Koolaman. The planning and development of these deposits is at pre-feasibility stage.

In September 2006, Adelaide Resources Ltd and Iluka Resources announced inferred resources for the Tripitaka heavy mineral sand deposit in their Colona Joint Venture area, 90 km south east of the Jacinth and Ambrosia deposits in South Australia. The total inferred resource amounted to 42 Mt at 2.4% heavy minerals comprising 65% zircon, 5% rutile and 9% ilmenite. The Tripitaka discovery was followed by the discovery of the Gulliver's Prospect, about 160 km south east of Tripitaka and 60 km east of Ceduna in South Australia. Iluka reported that pre-feasibility work for the Eucla Basin deposits is being undertaken in the context of their remote location of the Eucla Basin deposits and major infrastructure requirements for their potential development.

To the end of 2006, Consolidated Rutile Ltd's operations at the Yarraman and Enterprise mines on North Stradbroke Island produced 72,217 t rutile, up 1% on 2005, and 52,963 t zircon, down 1% on 2005. The ilmenite production increased by 10% to 176,802 t. The production figures include output from a dry mill plant.

The TiWest Joint Venture (Exxaro Australia Pty Ltd 50%, Tronox Incorporated 50%) operates an integrated titanium dioxide project in Western Australia, incorporating a dredging and dry-mining heavy mineral sands operation at Cooljarloo, dry separation and synthetic rutile plants at Chandala and a titanium dioxide pigment plant at Kwinana. Production in 2006 was approximately 454,000 t of ilmenite, 72,000 t of zircon, 36,000 t of rutile, 196,000 t of leucosene, 28,000 t of synthetic rutile and 108,000 t of TiO<sub>2</sub> pigment. The Tiwest Joint Venture partners announced that the Kwinana plant was expanding from its current annual capacity from 110,000 t to 150,000 to 160,000 tpa TiO<sub>2</sub> pigment, which is projected to be the world's largest pigment producing region by 2010.

The heavy mineral resources/reserves controlled by BeMax are located in old shorelines in two geological/geographic provinces – the Murray Basin of Victoria and New South Wales, and the South West region of Western Australia.

BeMax Resources NL reported that it has upgraded its resource base in the Murray Basin from 67.5 Mt of contained heavy minerals to 85.2 Mt. The additional resources were sourced in part from

- Delineation of the Massidon deposit with 10.7 Mt of contained heavy minerals,
- The discovery of two new deposits, the Coliban and the Wakool in the Willandra East tenement, increasing the resources by 3.5 Mt to a total of 16.2 Mt, and
- Discovery of the Barda deposit in the Willandra West tenement, increasing resources of this tenement by 1.9 Mt to 11.3 Mt.

BeMax reported that the commissioning of the Ginkgo mine and the Broken Hill mineral separation plant were completed during the first half of 2006. Production from the Ginkgo mine in 2006 amounted to 33,136 t ilmenite, 32,711 t leucosene, 33,306 t rutile, and 19,663 t zircon. BeMax had completed detailed pre-feasibility studies and lodged environmental assessment documentation for the nearby Snapper mine. The company also reported that design and engineering requirements and statutory approvals to expand the mineral separation plant in Broken Hill were well advanced.

BeMax's heavy mineral sand resources in South West region of Western Australia in 2006 amounted to 141 Mt at 9.6% heavy minerals comprising 82% ilmenite and 9% zircon. In 2006, BeMax's operations in the region produced 372,063 t of heavy mineral concentrate comprising 242,373 t of ilmenite, 7,222 t of secondary ilmenite, 7,046 t of leucoxene and 18,749 t of zircon. Production in 2006 was sourced from the Ludlow and the Tutunup South mines. The company's Gwindinup project comprises the Gwindinup North and South deposits and the extensions of Happy Valley North and South deposits (see [www.australianminesatlas.gov.au](http://www.australianminesatlas.gov.au)). Approval for the development of the Gwindinup deposit was received at the end of 2005 and they will come on line when operations are completed at Ludlow during 2007. Approval applications for the Happy Valley deposit are progressing.

Matilda Minerals Ltd announced updated reserves of 6.5 Mt at 4.5% heavy minerals for their Tiwi Islands mineral sands project in Northern Territory. The Tiwi Islands are located north of Darwin and comprise the Melville Island in the east and the Bathurst in the west. The reserves are contained in three deposits, the Andranangoo and the Lethbridge on the north coast of the Melville Island and the Puwanapi on the west coast of the Bathurst Island. The deposits contain 106,000 t zircon, 56,000 t rutile 34,000 t leucoxene and 59,000 t ilmenite. The company commenced mining of the deposit in the second half of 2006 and the processing plant reached full production in December 2006. The first shipment of concentrate will be scheduled after the wet season in 2007. Apart from Tiwi Islands, the company's other heavy mineral sand exploration activities include Carnarvon, Broome and Cape York Peninsula.

At end of 2006, Australia Zircon NL was in process of constructing its Mindarie zircon mine in the western Murray Basin, 148 km east-north-east of Adelaide, South Australia. Reserves at the deposit amount to 59 Mt at 4.3% heavy minerals. The first shipments of products is anticipated to occur in the second half of 2007.

Australian Zircon NL also is earning an 80% participating interest in its WIM 150 Joint Venture with Austpac Resources NL. An aircore drilling program was completed by Australian Zircon to evaluate existing data from WIM 150 and the company is planning to excavate a bulk sample for gravity and dry mill test work. A pre-feasibility study is scheduled for completion before the end of 2007. Austpac has previously demonstrated that a +95% TiO<sub>2</sub> synthetic rutile can be produced from the fine WIM 150 ilmenite, and that the synthetic rutile product can be agglomerated.

Austpac Resources NL announced that a BHP Billiton funded research program to continue the development of Austpac's technology (ERMS SR) for production of high grade synthetic rutile and a direct reduced iron co-product from ilmenite is essentially complete. A possible source for ilmenite being heavy mineral sand deposits in the Murray Basin some of which is returned to the pit in current mining operations because of chrome content and other impurities. The next step in the study is to construct a 3,000 tpa integrated demonstration plant. Subject to successful results from the demonstration plant, Austpac and BHP Billiton will consider a 60,000 tpa commercial plant.

Monto Minerals reported at end of 2006 that the construction of a heavy minerals mine at Goondicum was in progress. Initially three industrial minerals will be produced from the deposit – apatite, feldspar and ilmenite. Currently titanomagnetite is under advanced technical and commercial product evaluation. It is anticipated the mine will begin commercial production in the second half of 2007. The deposit comprises weathered eluvial and alluvial material developed over the Goondicum Gabbro, located about 120 km south of Gladstone, Queensland.

Gunson Resources Ltd reported good progress with environmental approvals for its Coburn heavy mineral sand project in Western Australia. The deposit has an indicated resource of 305 Mt with 1.4% heavy minerals and an additional 420 Mt of inferred resource at 1.4% heavy minerals. The company stated that the completion of the definitive feasibility study was held back until the government permitting process is finalised.

Image Resources Ltd reported that in their joint venture area with Metal Sands Pty Ltd at Cooljarloo, ongoing exploration increased the shallow strand targets from 2 to 16 for a total strike length of 45 km and deeper channel targets increased from 4 to 20 totalling 50 km strike length. The company is using distinctive ground magnetic signatures to define the deep-seated channel heavy mineral targets. It believes that the thick channel-like mineralisation occurs in older Mesozoic sediments underlying the Pleistocene sediments with shallow heavy mineral deposits. Results from recent drilling programs include 66 m at 2.1% heavy minerals from 14 m. The company is also exploring other parts of the north Perth Basin including North Cooljarloo, Bidaminna and Wannamal.

Astron Ltd's Donald project comprises the Donald (WIM 250) and Jackson (WIM 200) heavy mineral sand deposits in the Murray Basin in Victoria. In January 2006 the company reported a total indicated and inferred resource for the project of 693 Mt with a heavy mineral content of 5.1%. Contained within this resource is an indicated and inferred resource of 477 Mt at 1.1% zircon, 1.8% ilmenite, 0.3% rutile and 1.1% leucoxene. The project is planned to be a 7.5 Mtpa mining operation, producing 500,000 tpa of heavy mineral concentrate for export to China. The company reported that metallurgical test work for the Donald concentrate upgrade plant has been completed, environmental studies were in progress, a production well to assess the groundwater from the Avon Deep Lead had been developed and the preferred start-up location for the Donald mining operation has been confirmed.

In April 2006, Olympia Resources NL reported that they had entered into a life-of-mine toll treatment for the Keysbrook deposit with Cable Sands (WA) Pty Ltd whereby Cable Sands will treat wet concentrates from the Keysbrook deposit. The final environmental approvals are not expected before mid-2007 and the first production is now scheduled for mid-2008.

During 2006, Mineral Sands Ltd issued a prospectus outlining extensive mining tenements covering heavy mineral deposits and prospective areas for heavy minerals in the Murray Basin, the Eucla Basin, the Yaringa area in the coastal Gascoyne district of Western Australia and the Inkerman Project made up of mining tenements along the western coast of Cape York Peninsula. The Murray Basin projects include three deposits, the Wedderburn with indicated and inferred resources of 173.2 Mt at 4.4% heavy minerals containing 14.4% zircon, Graybridge with 47.6 Mt of inferred resources at 3.42% heavy minerals containing 15.19% zircon, and Avonbank with 206 Mt of indicated and inferred resources at 5.54% heavy minerals containing 15.38% zircon.

## Molybdenum

Molybdenum (Mo) is used in steels and superalloys to enhance strength, toughness and corrosion resistance. The main commercial source of molybdenum is molybdenite ( $\text{MoS}_2$ ), however it is also found in minerals such as wulfenite ( $\text{PbMoO}_4$ ) and powellite ( $\text{CaMoO}_4$ ). Molybdenum is mined as a principal ore and is also recovered as a by-product or co-product of copper and tungsten mining.

### Resources

Molybdenum occurs as the primary metal sulphide minerals in low-grade porphyry molybdenite deposits and as an associated metal sulphide in low-grade porphyry copper deposits.

EDR of 400 t of molybdenum remains unchanged compared to 2006. Most of Australia's demonstrated resources of molybdenum are classified as paramarginal. Over 95% of the paramarginal demonstrated resources occur in the Spinifex Ridge deposit in Western Australia.

### Exploration

Data relating to exploration for molybdenum are not available nationally.

### Production

Currently there is no molybdenum production in Australia.

## World Ranking

The distribution of molybdenum resources and production is concentrated in only a few countries in the world, with China, USA, Chile and Canada holding about 85% of the resources. In 2006, world economic resources are estimated to be about 8,600 kt based on USGS data.

World production in 2006, based on USGS estimates amounted to 179,000 t of molybdenum. In 2006, production was dominated by USA, with 60,500 t followed by China (41,000 t) and Chile (38,700 t). USA, China and Chile accounted for nearly 80% of global outputs in 2006.

## Industry Developments

Moly Mines Ltd is undertaking a full feasibility study of its Spinifex Ridge molybdenum - copper project in the Pilbara region of Western Australia. Final mine planning is currently underway.

# Nickel

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

## Resources

Australia's EDR of nickel was virtually unchanged in 2006 with a small decrease of 0.8% from 23.9 Mt to 23.7 Mt.

Western Australia remains the largest holder of nickel resources with more than 90% of total Australian EDR. New South Wales is the second largest with 6.6%, followed by Queensland (2.8%), Tasmania (0.3%) and Northern Territory (0.1%). Nickel resources in both New South Wales and Queensland are associated with laterite deposits, but EDR in Tasmania and the Northern Territory are mostly sulphides.

Subeconomic demonstrated resources, which accounted for about 7.1% of total identified resources, remained virtually unchanged during the review period. The paramarginal resources were unchanged while the submarginal resources increased by 0.1 Mt in 2006. Western Australia has 80% of the subeconomic nickel resources.

Inferred resources increased by 1.9 Mt (9%) to 22.2 Mt in 2006. Western Australia maintained its dominant share of Australia's inferred resources with 91% followed by Queensland with 6%.

The ratio of inferred resources to EDR in 2006 was 0.93 to 1.

## Accessible EDR

Currently, all nickel EDR is accessible for mining. At the rate of production in 2006, AEDR of nickel are sufficient for an average of almost 130 years.

## JORC Reserves

About 29% of AEDR comprise JORC Code reserve. The remaining 71% 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 38 years at current rates of production.



## Exploration

Expenditure on nickel-cobalt exploration for 2006 calendar year, as reported by ABS, was A\$147.9 million, a decrease of 12% compared with 2005. Western Australia attracted most of this expenditure with \$113.1 million. Nickel sulphide and lateritic nickel deposits in the Yilgarn Craton, Western Australia continued to attract the bulk of the exploration expenditure followed by significant activity in the Pilbara and Kimberley. Other States with significant nickel-cobalt exploration included Queensland, Tasmania and South Australia.

## Production

Australia's nickel production decreased in 2006 by 2.0% to 185 kt, as reported by ABARE, all of the production from Western Australia. The value of all nickel products exported was 5.5 billion. Australia was the world's third-largest producer, accounting for 12% of estimated international nickel output.

## World Ranking

Based on figures published by the USGS and modified to incorporate the locally reported Australian resources reported here, world EDR of nickel decreased by 0.5% to 63.8 Mt in 2006 from 64.1 Mt in 2005. Australia's share of world EDR was 37.1% in 2006, which was down 0.2% from 2005, and it remained the largest holder of EDR followed by Russia (10%), Cuba (8.8%) and Canada (7.7%).

Russia was the largest producer again with 320 kt (20.7%), followed by Canada with 230 kt (14.9%) and Australia with 185 kt (12%). The fourth largest producer was Indonesia with 145 kt (10%) and New Caledonia with an output of 112 kt (7.3%).

## Industry Developments

ABARE reported that the lead time required to develop new mine and concentrate production capacity is expected to constrain nickel supply growth prior to 2008. This constraint, coupled with moderate demand growth, is expected to keep nickel prices well above their long term average in the period to 2008. The average nickel price for 2006 was about US\$24,252/t.

Australia has several nickel sulphide mines currently in operation. With the exception of the Avebury mine operated by Allegiance Mining NL in Tasmania, all are in Western Australia. They include BHP Billiton's Leinster and Mount Keith; LionOre Mining International Limited's Black Swan and Emily Ann; Jubilee Mines NL's Cosmos; Mincor Resources NL's Miitel, Redross, Mariners, Wannaway; Independence Gold NL's Long-Victor and Consolidated Minerals Limited's Beta Hunt operation. Nickel sulphides are mined also by Sally Malay Mining Limited at Sally Malay mine and the company, in a joint venture with Brilliant Mining Corp, continued mining at the Lanfrachi mine. Mining continued also at Australian Mining NL's Blair mine and at the Radio Hill deposit operated by Fox Resources Ltd. New nickel sulphide mines to start up were Western Areas NL's Flying Fox deposit and LionOre commenced mining of its Waterloo deposit. Two laterite nickel mines were in operation: OM Group's Cawse and Minara Resources NL's Murrin Murrin. In November 2006, OMG entered into a definitive agreement to sell all of its nickel assets, including the Cawse nickel mine, to OJSC MMC Norilsk Nickel. Western Australia also has a nickel smelter at Kalgoorlie and a refinery at Kwinana as well as BHP Billiton's concentrators at Kambalda Leinster and Mt Keith which processes ores from third party operators. Another refinery is located at Yabulu, Queensland.

In its 2006 Annual Report to the United States (Form 20-F), BHP Billiton reported that its West Australian operations produced 100,100 t of contained nickel-in-concentrate to the year ended 30 June 2006. Most of the nickel production was sourced from the Mt Keith and Leinster mines but some production was from ores purchased feed from third parties.

Most of the nickel ore treated at the Kambalda, Leinster and Mt Keith concentrators is smelted into nickel matte containing about 68% nickel at the Kalgoorlie nickel smelter. The mill and concentrator at Kambalda are supplied with third party ore and produce concentrate containing about 13% nickel.

Some of the nickel matte was sold to overseas customers but most of it was refined at BHP Billiton's Kwinana nickel refinery to produce LME accredited nickel briquettes, nickel powder and other intermediate products such as cobalt-nickel-sulphide. The Kwinana nickel refinery has a capacity of 70,000 tpa of nickel metal.

In March 2007, BHP Billiton approved another revision of costs to allocate US\$2.2 billion for development at the Ravensthorpe mine site in Western Australia and US\$556 million for expansion of the Yabulu refinery in Townsville, Queensland. The Ravensthorpe project is based on three laterite nickel deposits with a combined proved and probable reserves of 238 Mt at 0.68% Ni and includes development of an open cut mine, hydrometallurgical treatment plant and associated infrastructure. The hydrometallurgical process plant is designed to treat both limonite and saprolite ores and produce up to 220,000 t of mixed nickel-cobalt hydroxide intermediate product containing up to 50,000 t of nickel and 1,400 t of cobalt which will be shipped from Esperance to the QNI Yabulu for refining. The refining section of Yabulu is being expanded to increase production to 76,000 t of nickel and 3,500 t of cobalt. In its quarterly report for March 2007 the company reported that the Ravensthorpe project was 90% complete and the Yabulu expansion was mechanically complete and commissioning would start ahead of the delivery from Ravensthorpe. The commissioning of ore processing facilities at Ravensthorpe was in progress following the initial delivery of ore in the 1st quarter of 2007. The target date for the first metal produced at Yabulu from the Ravensthorpe project is now the 1st quarter of the calendar year 2008.

It was reported in the media that BHP Billiton also was reviewing the scoping study of its Nebo-Babel deposit in the Musgrave region which was reported to have a preliminary resource estimate of 392 Mt grading 0.3% Ni, 0.3% Cu and 0.18 gm/t PGEs.

LionOre Mining International Limited reported production figures for 2006 of 1,200,785 t at 0.6% Ni from the Black Swan open pit and 151,825 t at 3.95% Ni from the Silver Swan underground mine. The operations produced a total of 45,216 t of concentrate for 7,190 t Ni. LionOre's Lake Johnston operations of Emily Ann and Maggie Hays mines, produced 72,457 t of concentrates for 9,737 t Ni. The Maggie Hays plant upgrade was completed during 2006 and the full capacity of 1.5 Mtpa was reached by the end of November 2006. The resources at the Emily Ann mine are expected to be depleted by the 2nd quarter of 2007. LionOre commenced mining at the Waterloo mine in October 2006 and produced 57,818 t of ore at 3.08% Ni for 1,077t of Ni.

LionOre is continuing with feasibility studies for its Honeymoon Well deposit, including the potential use of Activox process. The feasibility study is due for completion in the 3rd quarter of 2007.

During the first half of 2007, LionOre reached an agreement with Norilsk Nickel for a takeover by Norilsk.

Production from Jubilee Mines NL Cosmos deeps orebody in 2006 amounted to 11,437 t Ni. During 2006 the company continued to mine the Cosmos deeps deposit which was depleted in early 2007. Mining began at the Alec Mairs 1 deposit in December 2006 followed by the Alec Mairs 2 and Tapinos deposits in early 2007. The company was conducting a feasibility study also on the Sinclair deposit and conceptual underground mining studies were carried out on the Anomaly 1 deposit. The Helene Decline also was being advanced towards the Prospero deposit.

Western Areas NL reported that at end of 2006 its Flying Fox deposit contained a total of 77,590 t of indicated and 12,920 t of inferred nickel metal in six ore bodies. Two ore drives were established at the T Zero orebody and massive ore assaying 8% Ni was being mined with the first shipment of ore treated in LionOre's concentrator at Lake Johnston. A pre-feasibility study is scheduled for completion in May 2007 on the Diggers South deposit which has indicated and inferred resources at the deposit amounting to about 30,500 t of nickel metal. Continuing exploration at the deposit included an intersection of 25.1 m at 1.6% Ni from 285.8 m downhole depth. The company also is investigating the New Morning/Daybreak deposits which have indicated and inferred resources of 30,700 t of contained nickel.

During 2006, Sally Malay Mining Limited's underground mine operation at Sally Malay produced 7,369 t Ni, 3,431 t Cu, and 389 t Co. Infill drilling is being conducted to delineate additional ore at the mine and a revised resource statement is anticipated in the second half of 2007. The company also announced an increase in the resources of the nearby Copernicus deposit to 852,000 t at 1.24% Ni which is being developed in a joint venture between Sally Malay Mining Limited (earning 60%) and Thundelarra Exploration Limited (40%). Sally Malay holds 75% and is operator of the Lanfranchi joint venture nickel project. In 2006 Lanfranchi produced 4,766 t of Ni and 410 t of Cu. Development began in November 2006 of the high grade Winner orebody, which has an indicated resource of 6,147 t of Ni, and another 2,438 t of contained Ni in the underlying Schmitz Extension orebody. Both the Winner and Schmitz Extension orebodies are planned for mining in 2007. In October 2006 the company announced the discovery of the Deacon mineralisation in the Lanfranchi area and has released results of drillhole sample analyses which include 30.5 m at 4.5% Ni. An exploration drive was established by the end of 2006 to evaluate the discovery.

Mincor Resources NL operated four nickel mines south of Kambalda in Western Australia in 2006, comprising the Miitel, Redross, Mariners and the Wannaway mines. The combined metal in concentrate production for these mines in 2006 was 13,630 t Ni, 1,236 t Cu and 267 t Co. Small scale remnant mining continued at the Wannaway mine. During 2006 the company carried out a major expansion of the Miitel mining operation with a \$24 million development of the South Miitel orebody. Mincor also entered into a farm-in agreement with View Resources Limited to earn 70% equity in the Carnilya Hill tenements where drilling by Mincor encountered promising intersections, including 10.71 m at 6.95% Ni. The company started a prefeasibility study in November 2006 on the development of a new nickel mine at Carnilya Hill. In December 2006 Mincor also announced the discovery of new nickel mineralisation below the Mariners mine, including an intersection of 6.55 m at 7.8% Ni from 211.08 m downhole. The company also acquired a portfolio of historic Kambalda nickel mines from Goldfields Mine Management Pty Ltd for \$30 million in cash plus a royalty.

Fox Resources Limited achieved nickel production to mid 2006 totalling 551 t Ni and 776 t Cu from its Radio Hill. The company completed a bankable feasibility study in January 2007 on the lower grade nickel mineralisation at Radio Hill which indicated a mining reserve containing 6,000 t Ni, 8,200 t Cu and 350 t Co with additional resources at the Sholl B2 deposit. The company also announced drill results of disseminated and massive stringer sulphide Ni-Cu mineralisation at the Razerline prospect which included a drillhole intersection of 19.9 m at 0.64% Ni and 0.61% Cu at 113.1 m downhole depth.

Allegiance Mining NL reported at the end of 2006 that all infrastructure for the Avebury mine near Zeehan in Tasmania was installed and fully operational. Development ore was produced from the North Avebury development drive in January 2007. Construction of the processing plant was well advanced and scheduled for production by the 4th quarter of 2007. During 2006, the company announced the discovery of the Saxon and Bison mineralised zones. The company considers the Saxon discovery may represent a new line-of-lode parallel to the East Avebury line-of-lode.

Australian Mines Limited reported that production from its Blair nickel mine in 2006 amounted to 1,181 t Ni. The capital development of the Blair Main decline was recommenced to secure medium to long term access to deeper nickel sources. Ongoing exploration drilling results at the mine included 9.25 m at 12.5% Ni. The company acquired the Marriott nickel deposit and commenced exploration to locate extensions to the existing resources of 550,000 t at 1.4% Ni. Best drilling results included 17 m at 0.91% Ni from 81 m and 6 m at 1.79% Ni from 101 m. Exploration also was continued at the Blair South prospect through the company's Golden Ridge joint venture which included a drill intersection of 17 m at 1.16% Ni and 0.12% Cu from 99 m.

Independence Group NL reported total production for 2006 of 8,291 t Ni and 607 t Cu. The production was sourced from the Long, Victor South and the new McLeay orebodies. The company is continuing to explore for extensions of ore south of the Long and Victor-McLeay orebodies. Independence is conducting regional nickel exploration also in several areas in the Yilgarn, including the Duketon Nickel Joint Venture where 25 m at 0.73% Ni, 298 ppm Cu and 310 ppb Pt+Pd was intersected in a drill hole from 40 m depth at the Bulge prospect.

Consolidated Minerals Limited reported a production of 4,052 t Ni in 2006 from its Beta Hunt operation. The company continued decline development and exploration drilling the nearby East Alpha deposit and announced an updated resource of 551,000 t at 4.48% Ni for 24,700 t of contained Ni. Work was in progress on conversion of the newly discovered Beta West Block to a minable reserve. The new nickel discovery at Gillet Prospect was announced in September 2006 and included a drill hole intersection of 59.89 m at 1.64% Ni from 250.25 m. Consolidated Minerals was conducting resource delineation at the 132N, Widgie Townsite, Armstrong and Munda deposits in the Widgiemooltha area.

Metallica Minerals Limited has updated the lateritic nickel resources of the NORNICO group of lateritic deposits to 29.7 Mt at 0.75% Ni and 0.03% Co with a 0.45% Ni cut-off while the resource for the Lucky Break deposits remains at 1.022 Mt at 0.8% Ni and 0.05% Co. The company continued heap leach testing and prefeasibility studies on the NORNICO deposits. Metallica's joint venture partner on the Lucky Break Project, Metals Finance Corporation, was expected to complete a feasibility study by the end of March 2007. Experience from the feasibility study and the proposed development of Lucky Break is intended to serve as a major part of the much larger NORNICO feasibility studies which envisage a 1.5 Mtpa heap leach operation planned to produce about 10,000 tpa Ni.

Australasian Resources Limited, previously Sherlock Bay Nickel Corporation Limited, continued with feasibility studies, on its Discovery nickel deposit at Sherlock Bay, to evaluate a 'BioHeap' leaching process of low grade disseminated nickel sulphide ore.

On 30 July 2005, Heron Resources Limited signed a definitive farm-in and joint venture agreement with Inco Limited (now CVRD-Inco Limited) providing for the potential development of the Kalgoorlie Nickel Project (KNP). One of the main objectives for CVRD-Inco in its feasibility studies will be to evaluate whether a plant-scale screen upgrade to 1.5% Ni is achievable. During 2006, CVRD-Inco Limited commenced Step 2 of the KNP study which includes intensive drilling and metallurgical work followed by preparation for Step 3 of the study. Under the terms of the agreement, the pre-feasibility study must be completed by January 2009 with the feasibility study finished by July 2011. The agreement also requires that subject to a positive bankable feasibility study result, a decision to mine must be made before 2013. In October 2006 Heron announced the start of a heap leach project for the Jump-up Dam deposit which is outside its KNP study with CVRD-Inco. The Jump-up Dam deposit has an inferred resource of 41.1 Mt grading 0.82% Ni and a scoping study is underway with a 500 tpa to 1,000 tpa demonstration plant planned for 2007/08 and commercial production in 2009 at 5,000 tpa ramping up to 10,000 tpa.

The annual production for 2006 from the Murrin Murrin lateritic nickel plant operated by Minara Resources Limited amounted to 31,524 t Ni and 2,096 t Co. The company also started construction of a \$25 million heap leach demonstration plant in January 2006. It is anticipated that the plant will be operating at the rate of 2,000 tpa Ni metal and 150 tpa Co metal by the end of 2007.

OJSC MMC Norilsk Nickel reported an annual production of 5,686 t Ni from its lateritic Cawse deposit in Western Australia.

Tectonic Resources NL closed the small mining operation at RAV 8 in September 2005, but with appreciating nickel prices the company started delivery of small parcels of ore from low grade dumps in 2006. By December 2006 the company had produced about 77 t of Ni giving the total for the mine over more than six years 460,771 t of ore at 3.46% Ni for 15,944.6 t of Ni. In January 2007 the company announced it had reached an agreement with BHP Billiton to treat tailings material for delivery to the Kambalda concentrator. The company also reported that it was evaluating the reopening of the underground mine.

In September 2006 Compass Resources NL announced that its Browns oxide project had gained Northern Territory Government approval to begin operations, including construction and mining. It is anticipated production for export will be 10,000 tpa of copper cathode, 1,000 tpa of cobalt chemicals and 850 tpa of nickel chemicals over the next four years.

Metals X Limited was in the process of conducting a scoping study on its Wingellina nickel-cobalt oxide deposit and results at the end of 2006 suggested that the most optimal process route would be a 4 million tpa HPAL (high pressure acid leach) plant producing 40,000 tpa Ni metal. The company also is planning to explore its Claude Hills deposit to delineate additional nickel oxide resources and to test for possible nickel sulphides along the basal contact of the intrusion.

Gladstone Pacific Nickel Limited reported that an environmental impact statement is nearing completion for its proposed mining operation of lateritic nickel at Marlborough, Queensland, and for its proposed nickel processing plant at Yarwun, near Gladstone. The company also reported that an integrated definitive feasibility study was underway on processing of a blend of Marlborough ore (~30%) with east coast New Caledonian ore (~70%).

## Niobium

Niobium (Nb) and tantalum are often found together in the same ores due to their very similar chemical properties. Niobium is used in alloys by steel and aerospace industries and niobium-titanium alloy wire is utilised in the medical sector in magnetic resonance imaging. In Australia, niobium is only recovered as a by-product of tantalum mining at the Sons of Gwalia's Greenbushes mine (WA).

### Resources

Niobium EDR remained unchanged at 194,000 t in 2006. Most EDR of niobium is in the Greenbushes pegmatite with minor resources in New South Wales.

### Exploration

Data relating to exploration for niobium are not available.

### Production

It is estimated that a total of 200 t of niobium in export tantalum products was produced from the Greenbushes operation during 2006. Sons of Gwalia Ltd has been in administration since September 2004. In late 2006, Sons of Gwalia Ltd placed the Greenbushes tantalum mining operations into care-and-maintenance.

### World Ranking

Based on world estimates published by the USGS for 2006, the world's largest resources are located in Brazil with 4.3Mt of the estimated world EDR of 4.4Mt. Canada has the second largest EDR with 0.1 Mt, followed by Australia with about 0.03 Mt.

World production in 2006, based on USGS estimates amounted to 59,900 t. Production was dominated by Brazil with 56,000 t in 2006, however this figure is not complete for 2006. According to the USGS, other main producers were Canada (3,500 t) and Australia (200 t).

### Industry Developments

The niobium market is remarkably stable. Globally there are a very small number of producers that ensures that supply and demand are balanced. There were no major developments reported in Australia for 2006.

## Phosphate

Phosphate rock is a general term that refers to rock with high concentration of phosphate minerals, most commonly of the apatite group. It is the major resource mined to produce phosphate fertilisers for the agriculture sector. Phosphorous is also used in animal feed supplements, food preservatives, anti-corrosion agents, cosmetics, fungicides, ceramics, water treatment and metallurgy.



Australia's commercial resources of phosphate are in north west Queensland (Phosphate Hill, 140 km south east of Mount Isa) and on the Territory of Christmas Island in the Indian Ocean. 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 mono-ammonium phosphate (MAP) and di-ammonium phosphate (DAP) fertilisers for domestic and international use.

Christmas Island is a source of quality rock phosphate, which is exported to the Asia-Pacific region. The 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 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 compared to 2004. All EDR is sedimentary phosphate rock (phosphorites) from Phosphate Hill, which has an average grade of about 24%  $P_2O_5$ . There is no publicly available information on Christmas Island's phosphate resources.

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 south east of Laverton (WA), where a phosphate-rich zone has formed by the solution and weathering of a primary carbonatite.

The bulk of Australia's inferred phosphate resources are in phosphorites in the Georgina Basin, and these are distributed between Queensland and the Northern Territory.

### Exploration

Data relating to exploration for phosphate are not available.

### Production

There are three main locations for the production of phosphate rock; Phosphate Hill (Qld), Christmas Island and several small operations near Bendleby (SA). Production from Phosphate Hill for 2006 is estimated to be 2,082,658 t of phosphate rock. In South Australia, production for 2006 is estimated to amount to 1,925 t of phosphate rock, which is mainly used in industrial applications. No production figures are available for Christmas Island.

### 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

Incitec Pivot acquired Southern Cross Fertilisers from BHP Billiton on 1 August 2006. Phosphate Hill is a major production-based operations – phosphate mine and beneficiation, phosphoric acid, ammonia and granulation plants. Supporting facilities are located at Mount Isa (sulphuric acid plant) and Townsville (storage and ship handling facilities). Ore reserves at Phosphate Hill are sufficient to support production for more than 30 years.

In 2006 Phosphate Resources Ltd sought environmental approval for additional mining lease on Christmas Island under the *Environment Protection and Biodiversity Conservation Act 1999*. In May 2007, the Minister for the Environment and Water Resources announced the decision not to grant environmental approval for a proposed expansion of phosphate mining on the Christmas Island. The company has lodged a challenge to the decision not to grant new leases in the Federal Court

of Australia. The current mining leases on the island held by Phosphate Resources Ltd are not affected. However, granting the additional mine leases would extend phosphate operations from five to seven years, up to 10–12 years.

## Shale Oil

Oil shale is organic-rich shale, which yields substantial quantities of oil (shale oil) and combustible gas by heating and distillation. The organic material in oil shale is called kerogen, which under appropriate conditions in the crust can be a precursor to conventional oil reservoirs. One tonne of commercial grade oil shale may yield from about 100 to 200 litres of oil. Shale oil in today's world market is not competitive with petroleum. The availability and price of petroleum ultimately will govern the viability of a large-scale shale oil industry.

### Resources

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, which are relatively easy to mine compared to carbonate-bearing oil shales (marls) elsewhere in the world. Minor tasmanite oil shale, which also can be used as a source of bitumen, are located in northern Tasmania.

### Accessible EDR

Australia has 4.6 GL (29 million barrels) of shale oil EDR. This could increase significantly if research and development into processing shale oil was to result in the development of a commercial plant. Paramarginal and submarginal demonstrated resources are 202 GL (1.3 billion barrels) and 3719 GL (23.4 billion barrels) respectively.

### JORC Reserves

JORC Code reserves account for all of accessible EDR.

### Exploration

South east of Devonport in Tasmania, Boss Energy Ltd has announced plans to undertake extensive exploration work over the next two years to define the resource extent of the Tasmanite oil shale. Currently, exploration for oil shale in Queensland is currently limited.

### Production

There is no oil being extracted from oil shale in Australia. From 2000 to 2004, the Stage 1 demonstration-scale processing plant at the Stuart deposit near Gladstone in central Queensland produced more than 1.5 million barrels of oil using a rotary kiln retort. No oil has been produced since 2004 and the facility is currently in care-and-maintenance. However, design efforts continue on Stage 2 of development, the facility is maintained in operating condition to allow for further production testing if required.

The demonstration plant achieved stable production runs at or above 100% of design capacity solid feed rates of 6,000 t of shale per day and oil yield totalling 4,500 barrels per stream day, while maintaining product quality and adhering to EPA emissions limits. The oil products from the demonstration plant were Ultra Low Sulphur Naphtha (ULSN) 55 to 60% and Light Fuel Oil (LFO) 40 to 45%. The ULSN, which can be used to make petrol, diesel and jet fuel has a sulphur content of less than 1ppm. To put this into perspective, from January 1, 2008, the regulated maximum content of sulphur in premium unleaded petrol will be reduced from 150ppm to 50ppm.

### World Ranking

The 2004 Survey of Energy Resources by the World Energy Council (WEC) reported that total world resources of shale oil are estimated to exceed 3.3 trillion barrels. The largest known deposit is in

western USA, with other important deposits in Estonia, Brazil, Australia, Jordan and Morocco. Only Estonia, Brazil and China produce shale oil. The same WEC survey reported that oil production for 2002 was Estonia at 345.4 ML, Brazil at 197.2 ML and China 125.6 ML.

### Industry Developments

In early 2004, Southern Pacific Petroleum's oil shale assets were acquired by Queensland Energy Resources Ltd (QERL). Subsequently, QERL announced the successful completion of the Stuart Stage 1 demonstration plant. Stage 2, which is four times the capacity of Stage 1, is currently on hold while QERL focuses on conducting extensive research and design studies for the next phase of its Queensland oil shale operations.

## Tantalum

Tantalum minerals have more than 70 different chemical compositions, of which tantalite, microlite, and wodginite are of greatest economic importance. It is common practice to name any mineral concentrate containing tantalum as 'tantalite' primarily because it will be processed for the tantalum.

Australia, through the operations of Sons of Gwalia Ltd in south west Western Australia, is the world's largest producer of tantalum in the form of tantalum concentrates, producing at least half of world mine output. The company also controls the world's largest stock of tantalum resources, principally in its holdings at Greenbushes and Wodgina (WA). Sons of Gwalia Ltd has been in administration since September 2004, although the production and supply of tantalite continues.

Over the past few decades, the tantalum market has been characterised by long periods of stability because the world's two largest tantalum processors have entered into long-term, fixed price supply contracts with Sons of Gwalia Ltd. Although the arrangements have helped to keep prices in the open market fairly constant. The administration of Sons of Gwalia Ltd has resulted in the tantalum market undergoing structural change which has contributed to a downturn in demand and depressed raw material prices.

### Resources

In Western Australia, granitic rare-metal pegmatites are almost exclusively the dominant style of primary tantalum mineralisation. The only exceptions are the carbonatite style at the Mount Weld deposit in the eastern goldfields and an unusual form of subalkaline granite-syenite mineralisation at the Brockman deposit, south east of Halls Creek.

EDR of 52,000 t in 2006 remains unchanged under the national assessment classification groups. All of tantalum EDR is accessible for mining. Approximately 78% of AEDR comprises JORC Code ore reserves as reported by industry.

### Exploration

Data relating to exploration for tantalum are not available.

### Production

Sons of Gwalia Ltd has agreements to supply an estimated total 900 tpa to the two major tantalum processors until the end of 2008. In 2006, production of tantalite was estimated to be 584 t. All production is from the Wodgina mine as the Greenbushes tantalum operation has been placed into care-and-maintenance.

### World Resources and Production

Based on world estimates published by the USGS for 2006, Australia has more than 90% of the world's EDR of tantalum. Canada has the second largest resource base.

World production of tantalum in 2006 was estimated by Geoscience Australia (using WA Department of Industry and Resources and USGS data) to be 1,144 t, a decrease of 9% on 2005. Production was

dominated by Australia, with 584 t in 2006, which amounts to about 51% of world output, although this figure is not complete for 2006. According to the USGS, other main producers include Brazil with 260 t, Mozambique with 81 t, Canada with 70 t, Ethiopia with 70 t and Rwanda with 50 t.

### Industry Developments

Sons of Gwalia Ltd continues to operate the Wodgina mine under an administrator. Haddington International Resources was unable to secure a viable off-take price for its future production from Bald Hill (WA) and has placed the processing plant under care-and-maintenance. ABM Resources NL has closed its Dalgaringa (WA) operation and placed the facilities under care-and-maintenance.

## Thorium

Thorium oxide ( $\text{ThO}_2$ ) has one of the highest melting points of all oxides ( $3,300^\circ\text{C}$ ) and has been used in light bulb elements, lantern mantles, arc-light lamps, welding electrodes and in heat resistant ceramics.

Thorium also can be used as a nuclear fuel, through breeding to  $\text{U}^{233}$ . Several reactor concepts based on thorium fuel cycles are under consideration, but much development work is still required before the thorium fuel cycles can be commercialised. India is currently testing components for a 300 MWe (Megawatt electric) technology demonstrator thorium-fuelled reactor and may commence construction some time during the period 2007 to 2012.

A research program at Moscow's Kurchatov Institute involves the US company Thorium Power and US Government funding to develop thorium-uranium fuel for the existing Russian VVER-1000 reactors. More recently, the program has moved to the elimination of weapons grade plutonium by using it as thorium-plutonium fuel in nuclear reactors. While normal fuel uses enriched uranium oxide ( $\text{UO}_2$ ), the new design has a demountable centre portion and blanket arrangement, with plutonium fuel in the centre surrounded by a blanket of thorium uranium fuel. The  $\text{Th}^{232}$  becomes  $\text{U}^{233}$ , which is fissile, as is the core  $\text{Pu}^{239}$ . Blanket material remains in the reactor for nine years but the centre portion is burned for only three years (as in a normal VVER) (World Nuclear Association Information Paper – Thorium, May 2007).

Thorium Power of the US and Red Star, a nuclear design agency owned by the Russian Government, have signed an agreement for the Thorium Power seed and blanket fuel design to undergo irradiation testing aimed at moving towards its use in commercial reactors (*World Nuclear News*, 20 April 2007). Thorium Power recently announced the successful completion of a three year test of experimental thorium fuel rods and is planning further testing to qualify the fuel for widespread use, initially in VVERs, then in other current light water reactors, possibly in six years (*World Nuclear News*, 22 March 2007). The new alliance with Red Star is expected to accelerate the program and lead to demonstration of the fuel assemblies in a full-size commercial reactor.

According to Thorium Power, the fuel could stay in a reactor longer with parts of fuel assemblies remaining in a reactor for three or even nine years resulting in more of the highly-radioactive actinides produced by fission being burnt. Because of this, it is claimed that used thorium fuel will decay to background levels of radioactivity in around 100 years (*World Nuclear News*, 22 March 2007).

### Resources

There are no comprehensive detailed records on Australia's thorium resources because of the lack of large-scale commercial demand for thorium and a paucity of the required data.

Most of the known thorium resources in Australia are held in the monazite component of heavy mineral sand deposits, which are mined for their ilmenite, rutile, leucoxene and zircon content. Monazite is a rare earth-thorium phosphate mineral. Prior to 1996, monazite was being produced from heavy mineral sand operations and exported for extraction of rare earths. However, in current heavy mineral sand operations, the monazite is generally dispersed back through the original host sand (to avoid the concentration of radioactivity) when returning the mine site to an agreed land use. In doing so, the rare earths and thorium present in the monazite are negated as a resource as

it would not be economic to recover the dispersed monazite for its rare earth and thorium content. The monazite content of heavy mineral resources is seldom recorded by mining companies in published reports.

In recent years, new mineral sand deposits have been discovered in inland areas of Australia, including the Murray Basin in New South Wales, Victoria and South Australia and the Eucla Basin in South Australia and Western Australia. Most of the known resources of monazite are in Victoria and Western Australia. Mining has begun in the Murray basin deposits at Ginkgo in New South Wales and, Douglas in Victoria and construction of another inland heavy mineral mine is well under way at Mindarrie.

Using available data, Geoscience Australia estimates Australia's monazite resources to be around 5.2 Mt. Although monazite may contain in excess of 20% thorium, assuming an average thorium content of about 7% would place Australia's thorium resources in heavy mineral sand deposits at about 364,000 t.

Apart from heavy mineral sand deposits, thorium can also be present in other geological settings, including carbonatite intrusions and other alkaline complexes, veins and dykes. A significant example is the Nolans Bore rare earth, phosphate uranium deposit, which is in fluorapatite veins and dykes. This deposit contains about 60,600 t of  $\text{ThO}_2$  (53,300 t of Th) in 18.6 Mt of indicated and inferred ore grading at 3.1% rare earth oxides, 14%  $\text{P}_2\text{O}_5$ , 0.021%  $\text{U}_3\text{O}_8$  and 0.326%  $\text{ThO}_2$ .

In New South Wales, the Toongi alkaline trachyte plug is located 30 km south of Dubbo and hosts a measured resource of 35.7 Mt and 37.5 Mt of inferred resources grading 1.96%  $\text{ZrO}_2$ , 0.04%  $\text{HfO}_2$ , 0.46%  $\text{Nb}_2\text{O}_5$ , 0.03%  $\text{Ta}_2\text{O}_5$ , 0.14%  $\text{Y}_2\text{O}_3$ , 0.745% total REO, 0.014%  $\text{U}_3\text{O}_8$ , and 0.0478% Th giving a total tonnage of about 35,000 t Th.

Similarly the peralkaline granitic intrusions of the Narraburra Complex 177 km north west of Canberra contain anomalous amounts of zirconium, REO and low concentrations of thorium (55 Mt at 1000 g/t  $\text{ZrO}_2$ , 60 g/t  $\text{Y}_2\text{O}_3$ , 300 g/t REO, 40 g/t  $\text{HfO}_2$ , 80 g/t  $\text{NbO}_2$ , and 50 g/t  $\text{ThO}_2$ ).

As there is no established large scale demand and associated costing information for thorium, there is insufficient information to determine how much of Australia's thorium resources are economically viable for electricity power generation in thorium nuclear reactors.

## Exploration

There has been no widespread exploration for thorium in Australia apart from two exploration licences which have been reported to have been acquired primarily for thorium exploration in Queensland.

However thorium is a significant component of some deposits being explored for other commodities. As mentioned above, thorium is present in the Nolans Bore deposit and in the Toongi intrusives complex. Heavy mineral concentrations within the King Leopold Sandstone and the Warton Sandstone, which constitute the Durack Range uranium project, also contain up to 2% thorium in the heavy mineral concentrate (Northern Mining Limited – announcement to the Australian Stock Exchange 21 March, 2007).

## Production

There is no current production of thorium in Australia, but it is present in monazite currently being mined with other minerals in heavy mineral beach sand deposits. Prior to 1996, monazite was produced from heavy mineral sand operations and exported for extraction of rare earths but is no longer considered to be a commercially viable source of rare earths because of the disposal costs associated with the radioactive material containing thorium.

## World Ranking

OECD/NEA (2006) has compiled estimates of thorium resources on a country-by-country basis. The OECD/NEA report notes that the estimates are subjective due to variability in the quality of



the data, a lot of which is old and incomplete. Table 3 has been derived by Geoscience Australia from information presented in the OECD/NEA analysis. The total identified resources refer to RAR plus Inferred Resources recoverable at less than US\$80/kg Th. The table below includes quantitative estimates of undiscovered thorium resources for some countries.

**Table 3. Estimated thorium resources by country**

Country	Total Identified Thorium Resources ('000 t Th) <USD 80/kg Th		Undiscovered Resources ('000 t Th)
		%	
Australia	452	18.1	Not available
United States	400	16.0	274
Turkey	344	13.8	400 - 500
India	319	12.8	Not available
Venezuela	300	12.0	Not available
Brazil	221	8.9	329 - 700
Norway	132	5.3	132
Egypt	100	4.0	280
Russian Federation	75	3.0	Not available
Greenland	54	2.2	32
Canada	44	1.8	128
South Africa	18	0.7	130
Others	33	1.3	81
TOTAL	2492	99.9	1786 - 2257

Sources: Data for Australia compiled by Geoscience Australia; estimates for all other countries are from: OECD, 2006: *Red Book Retrospective. A review of Uranium Resources, Production and Demand from 1965 to 2003*.

The US Geological Survey in its annual Mineral Commodity Summaries has reported 300,000 t of thorium 'reserves' for Australia, but has added the qualification that the monazite would probably not be recovered for its thorium content unless there was demand for the rare earth metals in the monazite.

## Tin

Tin (Sn) is used in solders for joining metals and pipes, as a coating for steel cans and in metal alloys. The largest single application for tin is in solders, which accounts for about one third of total world consumption. Solders are used in light engineering applications such as plumbing and sheet metal work, in the motor vehicle industry and in cans for various uses. Another major application for tin is coating steel sheet in the manufacture of tinplate, which accounts for about 27% of world tin consumption. Tinplate is used for containers in the form of tin cans for food products, drinks, oils, paints, disinfectants and chemicals.

### Resources

Australia's total EDR at December 2006 was 246 kt tin, a significant increase on the 163 kt tin in 2005. Australia's EDR of tin are in the following deposits: Collingwood (North Qld); Renison Bell and Mount Bischoff (western Tas); Greenbushes and Mt Deans (WA).

### Accessible EDR

All of Australia's EDR for tin are unencumbered, and there are no restrictions to mining these deposits.



Concentration plant at Collingwood tin mine, Queensland (MetalsX Ltd)

### 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 2006, JORC Code reserves of tin accounted for approximately 56% of AEDR.

### Exploration

Stonehenge Metals Ltd continued exploration at several tin prospects in north west Tasmania where stratabound carbonate replacement mineralisation occurs adjacent to granitic intrusions. The main prospects are **Granville East**, **Federation Tin** and **Heemskirk**.

Malachite Resources completed a program of trenching and bulk sampling of greisen veins at the **Sheep Station Hill** tin-tungsten prospect, 20 km east of Inverell in northern New South Wales. The results will provide estimates of the average grade of the near surface portions of the greisen veins and outline areas which could be mined by shallow open cut and selective mining.

### Production

Australia's mine production in 2006 was 1,478 t tin in concentrates which was 47% less than in 2005 and 572 t of refined tin ingots, 4% less than 2005. Mine production of concentrates occurred at Collingwood (Qld), and Greenbushes (WA). The decrease in Australia's mine production resulted from the cessation of production at Renison mine (Tas) in late 2005. Refined tin was produced at Greenbushes from smelting of concentrates. Total exports for 2006 were 1,022 t tin valued at \$9 million.

### World Ranking

Australia's EDR for tin ranked number eight in the world with the major resources of EDR in China, Malaysia, Indonesia, Peru, Brazil and Bolivia.

## Industry Developments

Metals X Ltd (formerly called Bluestone Tin Ltd) was the main tin mining and exploration company in Australia for 2006. It operates the Collingwood mine, and owns Renison and Mount Bischoff mines which are under care-and-maintenance. Metals X also owns several undeveloped deposits, including Gillian (Qld).

**Collingwood mine:** 30 km south of Cooktown in north Queensland. Construction and commissioning of the concentrator was completed and production of concentrates began in January 2006. The operation is Australia's main tin producer with production at around 5,700 t of tin concentrate a year grading 60% Sn.

**Renison Bell mine:** 15 km north east of Zeehan in Tasmania. As a result of the fall in world tin prices, high A\$:US\$ exchange rates and productivity related matters, Metals X suspended the mining at Renison in October 2005 and placed the project on care-and-maintenance. The company reported that the Renison underground mine cannot achieve required operating levels without significant new capital investment.

**Rentails Project:** During the year Metals X completed additional sampling and validation drilling over the old mine tailings at Renison. Metallurgical test work continued on developing flotation and gravity processes to remove the sulphide minerals from the tailings prior to investigating the use of tin fuming technology to recover tin metal from the concentrates.

In 2006, Metals X acquired the rights to the **Gillian** tin project at Mt Garnet (north Qld). The previous owner, Otter Exploration NL, in its 1979 Annual Report quoted indicated resources of 2.5 Mt grading 0.70% to 0.90% Sn and is amenable to open pit mining. The ore mineralogy is complex and tin fuming methods are being investigated for metallurgical processing of the ores.

Sons of Gwalia Ltd produced 572 t refined tin ingots in 2006 from **Greenbushes** mine (WA), 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 with tin ingots produced from a smelter at the site.

Van Dieman Mines continued work to evaluate deep lead alluvial tin deposits in north east Tasmania. These deposits extend from the Blue Tier granite in the south through to the north east coast of Tasmania and extend off-shore into Ringarooma Bay. During the 1960s and 1970s a number of companies delineated significant resources of alluvial tin in the Scotia, Endurance, Central Ringarooma, Great Northern Plains and offshore deposits. In 2006, a pilot plant produced bulk samples of tin concentrate and sapphire for sorting and grading. Results from the bulk samples will be used to finalise plans for full-scale alluvial mining and processing which is proposed to commence in the latter part of 2007. Exploration continued in order to evaluate resources of the Great Northern Plains deposit and an airborne magnetics/radiometric survey was flown over the off-shore areas in Ringarooma Bay.

## Tungsten

Tungsten (W) metal and its alloys are among the hardest of all metals. It occurs as wolframite ((Fe,Mn)WO<sub>4</sub>) and scheelite (CaWO<sub>4</sub>). Tungsten carbide has a hardness approaching that of diamond and is used for cutting and wear-resistant materials primarily in the metalworking, mining, oil drilling and construction industries. Tungsten alloys are also used in electrodes, filaments for light bulbs, wire and other components for electrical, heating, lighting and welding applications.

### Resources

Australia's total EDR at December 2006 was 72.1 kt of tungsten. China has the world's largest resources of tungsten with approximately 60% of world resources. Other nations with large resources include Canada and Russia.

## Exploration

There was virtually no exploration for tungsten in Australia between 1980 and the end of 2004. Tungsten prices have risen substantially since late 2004, and more than doubled in 2005. Prices at December 2006 were around US\$200 per metric tonne unit (1 metric tonne unit equals 10 kg WO<sub>3</sub>). In response to the rises, a number of companies started exploration and evaluation of old tungsten mines and deposits mainly in north Queensland and Tasmania.

King Island Scheelite continued to seek regulatory approvals from the Tasmanian Government for development of the **King Island** tungsten deposit.

Vital Metals continued exploration and resource in-fill drilling at the **Watershed** project 25 km north east of the Mt Carbine mine in far north Queensland.

Queensland Ores Ltd submitted an Environmental Management Plan and mining lease applications to the Queensland Government for the **Wolfram Camp** tungsten-molybdenum project, 90 km west of Cairns, north Queensland. Wolframite and molybdenite mineralisation occur in high grade quartz pipes and also as disseminated lower grade mineralisation surrounding these pipes. Mineralisation is within granite and is adjacent to the margins of the granitic body where it intrudes sediments. The resources were reported as: measured resources 598,200 t averaging 0.42% WO<sub>3</sub> 0.17% MoS<sub>2</sub>; indicated resources 111,500 t averaging 0.41% WO<sub>3</sub> 0.16% MoS<sub>2</sub> and inferred resources 238,300 t averaging 0.4% WO<sub>3</sub> 0.2% MoS<sub>2</sub>.

Stonehenge Metals Ltd started exploration at the **Interview River** deposit in north west Tasmania. Tungsten-tin bearing veins occur within the youngest intrusive phase of the Interview granite.

## Production

Australia's only producing tungsten mine in 2006 was the Kara scheelite mine in north west Tasmania which produced 13 t of scheelite concentrates averaging approximately 55% WO<sub>3</sub>, representing 7.2 t contained WO<sub>3</sub> for the 2005–06 financial year. Scheelite (and magnetite) were produced from magnetite-pyroxene skarn within folded Ordovician limestone which is in contact with Devonian granite.

## Industry Developments

World production has been dominated by China, which, in recent years, has produced more than 80% of primary tungsten output. Other large producers were Russia and Austria. Over recent years the Chinese Government has taken steps to regulate production and control the release of Chinese tungsten on to the market. The lack of tungsten concentrate supplies from China and increased demand in China and elsewhere has resulted in higher prices during the past two years.

## Uranium

Major uses for uranium are as fuel in nuclear power reactors to generate electricity, in the manufacture of radioisotopes for medical applications and in nuclear science research using neutrons from reactors. Nuclear power currently supplies 16% of the world's electricity from 438 reactors providing 371 gigawatts (electrical) of generating capacity, which is more than seven times Australia's total from all sources. The United States has the largest number of reactors with 104, followed by France with 59, Japan with 55 and the United Kingdom with 19. Thirty countries were producing electricity from nuclear reactors in 2007 (source: World Nuclear Association). As at mid 2007, a further 32 reactors were under construction in 13 countries, notably China, South Korea, Japan and Russia.

Spot market prices for uranium rose sharply during the 2005 and 2006 calendar years which continued the trend of rising prices begun in late 2003. Spot market prices rose from US\$20/lb U<sub>3</sub>O<sub>8</sub> in January 2005 to US\$72 by December 2006 which was almost double the price at the start of 2006. It reached a peak of US\$138 in July 2007. The main reason for these rises was a reduction in uranium supplies from secondary sources, particularly material supplied from the blending down of highly enriched uranium in military stockpiles. The growing interest in nuclear power worldwide also

has influenced market prices along with rises in crude oil prices in recent years. In addition, concerns about climate change arising from increased greenhouse gas emissions has led to a renewed interest in nuclear power by governments in many countries because it is a fuel which produces minimal greenhouse gasses. Developing countries such as China and India are planning major expansions of nuclear power capacity and could become significant importers of uranium.

## 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 resources of **recoverable** 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 4. In previous years, resources in the less than US\$40 category were considered to be economic; however for 2006 resources in the less than US\$80 category are considered to be economic because of higher market prices.

**Table 4. Correlation of resource classification schemes for uranium.**

National Scheme	NEA/IAEA Scheme	Tonnes U recoverable (December 2006)	Tonnes U recoverable (August 2007) <sup>1</sup>
Economic Demonstrated Resources	Reasonably Assured Resources (RAR) recoverable at less than US\$80/ kg U	714 000	953 000
Paramarginal Demonstrated Resources	RAR recoverable at US\$80–130/ kg U	11 000	11 000
Submarginal Demonstrated Resources	RAR recoverable at greater than US\$130/ kg U	Not estimated	Not estimated
Economic Inferred Resources	Inferred Resources (IR) recoverable at less than US\$80/ kg U	502 000	577 000
Paramarginal Inferred Resources	IR recoverable at US\$80–130/ kg U	16 000	16 000

Australia's EDR were estimated to be 714,000 t U (or 841,980 t U<sub>3</sub>O<sub>8</sub>). During the year, exploration and development drilling resulted in increases in resources at the Ranger (NT), Mt Fitch (Rum Jungle area) (NT), Mt Gee (SA), Valhalla (Qld) and Westmoreland deposits (Qld). However, at the Olympic Dam deposit (SA), EDR decreased because the company reclassified portion of the measured and indicated resources into inferred resources. These changes were the result of a more conservative approach to estimating reserves and resources used by BHP Billiton than that used by the former owners WMC Resources Ltd. The net effect of all the above changes was that Australia's EDR decreased by 18,000 t U (2.5%) during the year ended December 2006.

Despite the fact that resources for Olympic Dam were reclassified into lower categories, it should be noted that the total resources for Olympic Dam in all NEA/IAEA resource categories increased by 47,000 t U to a total resource estimated to be 843,000 t U as at December 2006.

Australia's RAR recoverable at costs of less than US\$40/kg U were estimated to be 709,000 t U which represents 36% of world resources in this category (Note resources in the <US\$40/kg U category are included in the resources in <US\$80/kg U category).

<sup>1</sup> Since the compilation of resource estimates for Dec 2006, revised estimates of reserves/resources were released for the Olympic Dam deposit by BHPBilliton, Ranger 3 deposit by ERA Ltd, and Quasar Resources/Alliance Resources JV released the first estimates of resources for the 4 Mile deposit. Revised estimates of Australia's total uranium resources at August 2007 are shown here. These include the large increases in resources due to these deposits.



Australia had an additional 502,000 t U in inferred resources recoverable at costs of less than US\$80/kg U which is by far the world's largest resources in this category. These inferred resources are mainly in the south eastern part of the Olympic Dam deposit, where current drilling is defining large tonnages of additional resources.

Approximately 93% 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), and
- Kintyre and Yeelirrie (WA).

**Table 5. Uranium resources in States and the Northern Territory at December 2006<sup>2</sup>.**

	<b>Reasonably Assured Resources recoverable at &lt;US\$80/kg U Tonnes U</b>	<b>Inferred Resources recoverable at &lt;US\$80/kg U Tonnes U</b>	<b>Total Resources Tonnes U</b>	<b>Percentage of Australia's Total Resources</b>
South Australia	487 441	394 720	882 161	73%
Northern Territory	145 614	67 273	212 887	17%
Western Australia	59 595	20 158	79 753	7%
Queensland	21 358	19 769	41 127	3%
New South Wales	0	0	0	-
Victoria	0	0	0	-
Tasmania	0	0	0	-
Australia Total (rounded)	714 008 (714 000)	501 920 (577 000)	1 215 928 (1 216 000)	100%

### Accessible EDR

Approximately 21% of uranium EDR is inaccessible for mining. All uranium deposits in Western Australia and Queensland are classified as inaccessible resources because the respective State governments have policies banning uranium mining and development. In the Northern Territory, inaccessible resources are: i) Jabiluka deposit, because the traditional Aboriginal land owners have not granted approval to mine the deposit; and ii) Koongarra deposit where issues of Aboriginal land owner approvals to mine and environmental issues have yet to be resolved. Applications for new mine developments in the Northern Territory are subject to approval by the Australia Minister for Industry, Tourism and Resources. In South Australia, all resources are considered to be accessible because State government policies permit the development of new uranium mines.

<sup>2</sup> Uranium resources updated to August 2007 to include recent estimates for Olympic Dam, 4 Mile and Ranger 3 deposits.

	<b>Reasonably Assured Resources recoverable at &lt;US\$80/kg U Tonnes U</b>	<b>Inferred Resources recoverable at &lt;US\$80/kg U Tonnes U</b>	<b>Total Resources Tonnes U</b>	<b>Percentage of Australia's Total Resources</b>
South Australia	727 309	469 336	1 196 645	78%
Northern Territory	144 728	67 563	212 291	14%
Western Australia	59 595	20 158	79 753	5%
Queensland	21 358	19 769	41 127	3%
NSW, Vic, Tasmania	0	0	0	-
Australia Total (rounded)	952 990 (953 000)	576 826 (577 000)	1 529 816 (1 530 000)	100%

## 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 2006, JORC Code reserves of 342,000 t U account for approximately 61% of AEDR.

## World Ranking

Australia has the world's largest resources of uranium in RAR recoverable at <US\$80/kg U (equates to EDR), with 27% of world resources in this category at December 2006. Other countries with large resources include Kazakhstan with 14%, Canada with 13%, Niger with 7% and South Africa with 7% (Source: OECD/NEA & IAEA).

Australia also has the world's largest resources in RAR recoverable at <US\$40/kg U with 36% of world resources in this category.

Olympic Dam is the world's largest uranium deposit. Based on ore reserves and mineral resources reported by BHP Billiton as at June 2006, Geoscience Australia estimated that the deposit contains 476,000 t U in RAR recoverable at <US\$80/kg U. This represents almost 18% of the world's total resources in this category.

## Exploration

There was a resurgence in uranium exploration in Australia during 2005 and 2006 mainly because of the significant increases in spot market uranium prices in recent years. In 2006, more than 200 companies professed to have an interest in uranium compared with approximately 34 companies in the previous year. Expenditure on uranium exploration in 2006 was \$80.7 million, almost double the \$41.09 million for 2005 and more than five times the \$13.96 million expenditure for 2004.

Main areas (in terms of expenditure) were during 2006:

- South Australia – the Gawler Craton-Stuart Shelf region; Palaeogene sediments of the Frome Embayment; and palaeochannels overlying the Gawler Craton;
- Northern Territory – the Alligator Rivers region and Western Arnhem Land, Ngalia Basin (including Napperby project in Tertiary sediments overlying the Ngalia Basin); and
- Queensland – the Mount Isa province.

Significant discoveries during 2005 and 2006 included the Four Mile deposit (8 km north west of the Beverley mine, SA); major extensions of the Olympic Dam deposit; and extensions of Valhalla and Skal deposits in the Mt Isa region (Qld).

Drilling at **Four Mile** outlined a broad area of mineralisation covering five square km in Eocene sands of the Eyre Formation along the flanks of Proterozoic basement rocks of the North Flinders Ranges. Four Mile deposit is 8 km north west of the Beverley uranium mine. There are two deposits within this broad area: Four Mile West and Four Mile East. **Four Mile West** has been defined by close-spaced drilling and has inferred resources of 3.9 Mt averaging 0.37% U<sub>3</sub>O<sub>8</sub> which represents 15,000 t of contained U<sub>3</sub>O<sub>8</sub>. The average thickness of the mineralisation within the resource outline is 2.2 m and is hosted by fluvial sands at 140 to 170 m depth. Recent drilling at **Four Mile East** has intersected high grade mineralization and has become the focus for an intensive exploration drilling program with four rigs currently operating at the prospect. Best intersections to date include: 1.5 m @ 2.58% pU<sub>3</sub>O<sub>8</sub>; and 2.0 m @ 1.37% pU<sub>3</sub>O<sub>8</sub> (Note: pU<sub>3</sub>O<sub>8</sub> are radiometric grades in drill hole intersections as measured by downhole Prompt Fission Neutron probe).

In the **Mount Isa region**, Summit Resources continued drilling at brannerite-rich **Valhalla**, **Skal**, **Andersons**, **Mirrioola**, **Watta**, **Warwai**, **Bikini** and **Mirrioola** uranium-vanadium deposits. Drilling intersected mineralisation within hematite feldspar breccias at all these deposits. These deposits were drilled previously by Queensland Mines Ltd during the 1960s and Summit Resources has discovered extensions of the mineralisation, particularly at Valhalla and Skal. Valhalla has total indicated and inferred resources of 33.3 Mt averaging 0.077% U<sub>3</sub>O<sub>8</sub> which represents 25,900 t contained U<sub>3</sub>O<sub>8</sub>. Resources are being estimated for Skal, Andersons, Mirrioola, and Watta deposits.



Hydrated uranium oxide ('yellowcake') in 200 litre drums ready for shipment, Beverley in-situ leach uranium operation, South Australia (Heathgate Resources Ltd)

## Production

Production for 2006 from Australia's three uranium mines were Ranger 4,736 t  $U_3O_8$ , Olympic Dam 3,382 t  $U_3O_8$ , and Beverley in situ leach operations 825 t  $U_3O_8$  for a total Australian production of 8,943 t  $U_3O_8$  (7,584 t U), 20% lower than for 2005. The decrease in production was due to unscheduled plant maintenance at Olympic Dam and flooding of Ranger pit restricting access to high grade ore. Australia, with approximately 19% of world uranium production in 2006, is the world's second largest producer after Canada with 25%.

## Exports

Exports in 2006 were 8,660 t  $U_3O_8$  (7,344 t U) valued at A\$529 million. Exports of Australian uranium are controlled by stringent safeguards conditions which ensure that it is used only for peaceful purposes and does not enhance or contribute to any military applications. These conditions are given effect through bilateral safeguards agreements between Australia and the importing country. In the case of non-nuclear-weapon countries, it is a minimum requirement that IAEA safeguards apply to all existing and future nuclear activities in that country. In the case of countries with nuclear weapons, there must be a treaty-level assurance that Australian uranium will be used only for peaceful purposes and it must be subject to that country's safeguards agreement with the IAEA.

Australian mining companies supply uranium under long-term contracts to electricity utilities in United States, Japan, South Korea and Canada as well as members of the European Union including the United Kingdom, France, Germany, Spain, Sweden, Belgium, and Finland.

## Industry Developments

**Olympic Dam:** BHP Billiton is undertaking a two year pre-feasibility study into the expansion of Olympic Dam. The proposed expansion will more than treble annual production from the current capacity of 4,400 t  $U_3O_8$  per annum to approximately 15,000 t  $U_3O_8$  per annum. An Environmental Impact Statement is being prepared for the Australian and South Australian Governments. The Olympic Dam expansion project is scheduled to take seven years, with the first ore produced from the open pit in 2013–14. This expansion is based on a huge open pit to mine the south east portion of the deposit.

The Australian and State Governments have imposed a limit on the volume of groundwater which can be extracted from the Great Artesian Basin aquifers for use in the Olympic Dam operations and the nearby township of Roxby Downs. To overcome possible limitations on supply relative to demand, it is planned to develop a sea water desalination plant on Spencer Gulf, South Australia at an estimated cost of \$342 million to supply fresh water to the mine and town.

**Ranger mine (NT):** Production from Ranger mine in 2006 was approximately 20% lower than the previous year due to: higher than average rainfall restricting access to high grade ore, and operational difficulties within the acid plant.

The company reported total reserves of 50,869 t of contained  $U_3O_8$ , which is an increase of 11,000 t contained  $U_3O_8$  from the previous year. This increase is due to a decision to process low grade material. In addition, the company reported total resources of 43,253 t contained  $U_3O_8$ .

The 2006 exploration program identified potential extensions of the Ranger No 3 ore body at depth. The company is undertaking a feasibility study for expansion of the pit. If the expansion proceeds, then mining operation would extend to 2011. Milling from stockpiled ore will continue until 2020.

ERA recently announced the approval of a \$27.6 million laterite treatment plant and the first laterite ore is scheduled to be processed in early 2008 with production expected to extend for up to seven years. The plant will add approximately 400 t  $U_3O_8$  per annum. In addition, the company will build a \$13 million radiometric ore sorter, which will allow an additional 1,100 t  $U_3O_8$  to be produced by the end of 2013.

**Beverley (SA):** Heathgate Resources has identified new zones of uranium mineralisation extending to the east of the Mining Lease and additional mineralisation in an area to the south known as Deep South. In November 2006, the company applied for a new mining lease surrounding the existing Beverley lease. The extension to Beverley mine would substantially increase the life of the mine.

### Other Developments

Production from in situ leaching at UraniumOne's Honeymoon deposit, Australia's fourth uranium mine, is planned to commence in mid-2008 at 400 t  $U_3O_8$  per annum. Curnamona Energy Ltd is undertaking a field leach trial for the small Oban deposit (65 km north of Honeymoon mine). Both deposits are within Paleogene sands in the Frome Embayment of South Australia.

### CONSULTATIONS ON EXPANSION OF AUSTRALIA-RUSSIA AGREEMENT

In early 2007 Australia and the Russian Federation commenced negotiations on a new nuclear cooperation agreement which would replace the existing (1990) Australia-Russia nuclear cooperation agreement.

The proposed new agreement would allow Australian uranium producers to supply Russia's nuclear power industry, and would retain and build on the strict safeguards conditions contained in the existing agreement, and would include Australia's other safeguards agreements.

### NUCLEAR SAFEGUARDS AGREEMENT WITH CHINA

On 3 February 2007 the Australia-China Nuclear Transfer Agreement and Nuclear Cooperation Agreement came into force. The legal framework for Australian uranium producers to commence exports to China is in place. The timing and quantities of exports will be a matter for commercial negotiation.

### NEW GOVERNMENT INITIATIVE IN SUPPORT OF URANIUM EXPLORATION

The Australian Government announced in August 2005 that Geoscience Australia would receive \$58.9 million over 5 years under its Onshore Energy Security Initiative. The program will involve the acquisition of new seismic, radiometric, airborne electromagnetic and geochemical data to provide pre-competitive information to attract investment in exploration for onshore petroleum, geothermal, uranium and thorium energy sources. The data acquisitions will provide information which will significantly lower the risk for evaluating the potential prospectivity for energy related sources and other mineralisation.

The Onshore Energy Security Initiative will be implemented through the National Geoscience Agreement between the Australian Government, the States and the Northern Territory.

As part of the program, all available and new data will be considered in a uranium mineral systems framework to provide new concepts for uranium exploration, particularly in greenfields areas.

## Vanadium

Vanadium (V) is used in metal alloys with iron to produce high strength steel, which have a wide range of uses including structural applications such reinforcing bars in building and construction, gas and oil pipelines, tool steel, the manufacture of axles and crankshafts for the automobile industry, and jet engines for the aircraft industry.

Non-steel uses include welding, and alloys used in nuclear engineering and superconductors. Vanadium chemicals and catalysts are used in the manufacture of sulphuric acid, and desulphurisation of sour gas and oil.

Vanadium is sold in a number of forms; either as vanadium pentoxide ( $V_2O_5$ ), or less commonly as vanadium trioxide ( $V_2O_3$ ), or as an alloy of iron and vanadium most commonly as FeV80 (80% contained vanadium) or FeV50.  $V_2O_5$  is typically quoted in US\$ per pound, whilst FeV is quoted in US\$ per kilogram.

Mine production accounts for only about 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.

Vanadium prices have fluctuated over the past decade with sharp price rises and declines over short periods. Prices have ranged from US\$1.30 per pound  $V_2O_5$  to more than US\$20 per pound. The average prices have been in the range US\$3 to \$4 per pound.

### Resources

Based on the results of feasibility studies completed during 2006, the resources for deposits at Windimurra (75 km south east of Mount Magnet, WA), Balla Balla (mid-way between Karratha and Port Hedland, WA) and Gabanintha (43 km south east of Meekatharra, WA) were re-classified as EDR. Australia's EDR of vanadium increased from nil (in 2005) to 832 kt V in 2006. Historically, Australia's EDR have fluctuated because of the economic impacts of volatile prices and the nature of the vanadium market which is largely supplied from secondary sources that rapidly increase or decrease output in response to price trends.

### Exploration

Precious Metals Australia carried out exploration drilling to define the extent of a high grade ore zone to the west of the main Windimurra deposit (refer later section).

The results from an airborne magnetics and radiometrics surveys over the **Gabanintha** vanadiferous titanomagnetite deposit showed that the mineralised anorthosite extends for a further 4.2 km of strike length in areas not previously tested by drilling. To date, 8 km of the strike length have been tested, with 4.2 km remaining to be drilled. A drilling program is planned for 2007 to explore the extensions of the deposit.

### Production

There was no mining or production of vanadium in Australia during 2006. While there are a number of vanadium deposits in Australia, Windimurra has been the only deposit mined in recent years. Most of the world's mine production of vanadium during the year was from South Africa (40%), China (28%) and Russia (30%).



## Industry Developments

In July 2006, Precious Metals Australia Ltd completed a feasibility study into re-opening the **Windimurra** mine which is currently on care-and-maintenance. The study concluded that the project can be economically developed (Precious Metals Australia, Annual Report 2006). Annual production is planned to be 6200 t FeV80. Engineering studies and initial refurbishment of the processing plant began during 2006.

Windimurra mine and processing plant previously operated during the period from 2000 to 2003 when it treated 7 Mt of ore for the production of approximately 14,000 t V<sub>2</sub>O<sub>5</sub>. Production ceased in March 2003 and much of the plant and equipment was demolished and removed in early 2004 by the previous owner.

During 2006, the company completed a program of exploration drilling to test a zone of vanadium mineralisation immediately west of the known mineralisation. The results showed a zone of high grade mineralisation parallel to the main orebody.

Aurox Resources reported results of a feasibility study of the **Balla Balla** vanadium-titanium-iron ore project. It is proposed to develop the project in two stages. Stage 1 will be the construction of a concentrating plant to produce 2 Mtpa of titano-magnetite concentrates, and Stage 2 will be construction of a vanadium production circuit capable of producing 5,900 t FeV80 per year. During 1996, Aurox completed a 42 hole exploration drilling program which intersected extensions of the Balla Balla deposit for approximately 11 km beyond the proposed mining area (5 km long) (refer AIMR 2006 for description of geology and mineral resources for the Balla Balla deposit).

## Zinc, Lead, Silver

**Zinc** (Zn) is the 23rd most abundant element in the earth's crust the fourth most common metal in use after iron, aluminium, and copper. The construction and appliance manufacturing industries use large amounts of zinc, mainly as anti-corrosion coatings (galvanizing) on sheet steel, steel beams and vehicle panels. Around 4 Mt of zinc are used annually to protect around 100 Mt of steel, representing almost half the total world consumption of zinc. The widespread use of zinc as a protective coating is mainly because of its resistance to normal weathering. This is an electrochemical reaction known as galvanic action. Zinc is also used in brass, alloy die cast precision components, zinc pigments, zinc salts, zinc oxide as additives to rubber and for zinc chemicals in agriculture as well as for wrought or rolled zinc products. Zinc metal is produced in Australia at Sun Metals' Townsville refinery in Queensland and at smelters and refineries owned by Zinifex Ltd at Port Pirie in South Australia, Risdon in Tasmania, and Cockle Creek in New South Wales.

The widespread occurrence of **lead** (Pb), its relatively simple extraction and combination of desirable properties have made it useful to humans since at least 5,000 BC. In deposits mined today, lead (in the form of galena, PbS) is usually associated with zinc, silver and commonly copper (Cu) and is extracted as a co-product of these metals. More than half of the lead used today is 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, ceramics and glass in TV and computer screens for radiation protection. Uses for lead could increase in the future in large storage batteries used for load-levelling of electrical power and in electric vehicles.

The relative scarcity, attractive appearance and malleability of **silver** (Ag) make it suitable for use in jewellery, ornaments and silverware. Its extensive use in coins throughout history has declined over the past 40 years. In Australia, the 1966 50 cent piece was the last coin in general use to contain silver (80% Ag, 20% Cu). Silver is mined and produced mainly as a co-product of copper, lead, zinc, and to a lesser extent, gold (Au). Today, photographic paper and film, followed by the electronics and jewellery/tableware industries are the most important users of silver. Other uses include mirrors, as an anti-bacterial agent, for example in water treatment (as an ioniser with copper in domestic swimming pools) and for biocide and bacteriostatic activity in plastic and textiles formulations.

## Resources

Australia's total resources of zinc, lead and silver remained relatively stable in 2006. Total identified resources of zinc fell slightly from 89 Mt in 2005 to 87 Mt, lead from 57 Mt in 2005 to 54 Mt but silver remained unchanged at 107 kt.

## Zinc

Australian EDR of zinc at 40.6 Mt is the world's largest holding, accounting for almost 18% of world EDR. Queensland remained pre-eminent, its EDR slightly reduced at 25.6 Mt, which is 63% of national EDR, predominantly at Mt Isa, George Fisher and Century. The Northern Territory again had the second largest EDR with 10.5 Mt, constant at 26% of national EDR and all at the McArthur River deposit. New South Wales is third with EDR of 2 Mt (2.4 Mt in 2005) mostly at Endeavor and Broken Hill, and Western Australia is fourth at 1.6 Mt.

Paramarginal demonstrated resources of zinc doubled to 17 Mt while Submarginal demonstrated resources fell from 15 Mt to 2.5 Mt. The movement of resources to the higher subeconomic category reflects the improved prospects for economic viability with higher prices and consequent mine development.

Total inferred zinc resources increased from 25 Mt in 2005 to 27 Mt in 2006.

## Lead

Australia's EDR of lead decreased slightly in 2006 to 23.5 Mt of contained lead and constituted 44% of Australia's total identified lead resources (53.6 Mt). Australia also contains the largest share of world EDR for lead at 31%. Queensland retained the premier ranking with its EDR increasing from 14.2 Mt in 2005 to 14.9 Mt in 2006, which is a 64% share of national EDR. The Northern Territory decreased from 5.2 Mt to 5 Mt of EDR, or 21% of the national total due to depletion of resources through production at the McArthur River mine. New South Wales recorded another drop in EDR from 1.5 Mt in 2005 to 1.2 Mt, due to depletion of resources through production at Broken Hill. EDR in Western Australia decreased slightly from 2.2 Mt in 2005 to 2.1 Mt.

Australia's paramarginal demonstrated resources of lead are 8 Mt (3 Mt in 2005), which is 15% of total identified resources. Again, the movement of resources to the higher subeconomic category reflects the improved prospects for economic viability with higher prices and on-going mine development. In line with this movement Submarginal demonstrated resources decreased to 3 Mt (9 Mt in 2005) or 5% of total identified resources. Total inferred lead resources decreased from 21.9 Mt in 2005 to 19.6 Mt in 2006.

## Silver

EDR for silver are 46 kt which is 16% of world EDR. Queensland has 31 kt or 69% of Australian EDR, mainly in the Cannington, George Fisher, Mt Isa, and Century deposits. Most other holdings occur in South Australia (6 kt, largely at Olympic Dam and partly Prominent Hill), the Northern Territory (5 kt, largely at McArthur River and partly Browns), New South Wales (2 kt, largely Endeavor and Broken Hill) and Western Australia (1 kt, predominantly Golden Grove).

## Accessible EDR

All zinc, lead and silver EDR is accessible.

## JORC Reserves

Of Australia's EDR of zinc, 53% occurs in the JORC Code ore reserves categories, compared to a high of almost 65% in 2002. The remaining EDR comprise those measured and indicated resources as reported by mining companies, which Geoscience Australia considers will be economic over the long term. The zinc resource life using national EDR divided by annual production is 30 years, but using the ore reserve and dividing by annual production gives a resource life of only 16 years.

Of Australia's EDR of lead, 45% occurs in the JORC Code ore reserves categories. For lead, the national EDR/production ratio is 35 years, but if the ore reserve/production ratio is used it is 16 years. For silver, JORC Code reserves account for around 58% of EDR and resource life is 26 years by EDR or 15 years by reserves.

### Exploration

In 2006, exploration spending on zinc-lead-silver was \$101 million, \$54 million (53%) higher than in 2005. The 2006 expenditure was 24% of total base metal expenditure of \$426 million compared to 15% in 2005. Expenditure on exploration for zinc-lead-silver made up 7% of all mineral exploration which, excluding petroleum, was \$1.46 billion, and compared to 4% in 2005. Western Australia, Queensland and South Australia were the focus of much of this exploration expenditure.

### Production

The 2006 Australian mine production of zinc, lead and silver was 1.36 Mt, 0.67 Mt and 1.73 kt respectively. Production was lower for all three compared to 2005 with zinc marginally down by 5 kt or less than 1%, lead by 99 kt or 13%, and silver by 0.68 kt or 28%. Reduced production largely reflects mine and processing capacity development projects with concomitant outages. The majority of production was from Queensland which contributed 824 kt or 60% to national zinc production for 2006, along with 430 kt or 64% of lead, and 1.39 kt or 80% of silver. New South Wales produced 173 kt of zinc and 102 kt lead, Western Australia 142 kt zinc and 79 kt lead, Northern Territory 136 kt zinc and 30 kt lead and Tasmania 88 kt zinc and 28 kt lead.

The Century zinc mine, located approximately 250 km north of Mt Isa, close to the Gulf of Carpentaria in north west Queensland ranks second globally in zinc production. Century output of 599 kt of metal-in-concentrate in 2005–06 consisted mostly of zinc with around 10% lead. The Cannington mine, also located in north west Queensland, is the world's largest and lowest cost single mine producer of both silver and lead and a significant producer of zinc. Cannington produced 266 kt of lead, 1.2 kt of silver and 69 kt zinc in 2005–06.

The value of Australia's exports of zinc concentrates and refined zinc in 2006 totalled \$3.8 billion, 115% more than in 2005 (\$1.8 billion) and 2% of the value of total merchandise exports. The increase reflects higher zinc prices in 2006 with the average up by 118% to \$4,343/t compared to the average in 2005 of \$1,993/t. Exports of lead totalled 669 kt in 2006 and was valued at \$1.4 billion with the average price at \$1,996/t compared to the average of \$1,598/t in 2005. The value of Australia's mine production of silver in 2006 was around \$850 million.

### World Ranking

Based on USGS data for other countries, Australia has the world's largest EDR of both zinc (18% of the world) and lead (32%). Australia has the world's second largest EDR of silver (16%) behind Poland (18%).

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

### Industry Developments

**McArthur River (NT):** In October 2006, the final approvals required to convert the former underground mine to an open cut operation were received from the Australian and Northern Territory Governments. Underground mining operations ceased in 2006 and production was increased from the open cut test pit. The open cut development will include expanding the mine's footprint and diverting 5.5 km of the seasonal McArthur River around the open pit to enable production to continue for an additional 25 years. The capacity of the concentrator at McArthur River Mine is to be increased from 1.8 Mtpa of ore to 2.5 Mtpa, at a capital cost of \$37 million. The expansion will enable annual production of zinc-lead concentrate to increase from approximately 320 kt to around 430 kt of zinc-lead concentrate. The expansion also will include the potential to produce a bulk concentrate with lower lead content which can be processed in conventional smelters.

**Mt Isa (Qld):** During 2006, the Mt Isa zinc-lead concentrator re-vamp project Stage 1 was undertaken, increasing throughput capacity from 5 to 6.5 Mtpa. The second stage of the \$120 million, 60% expansion project involves the commissioning of a new milling and flotation circuit to increase capacity to 8 Mtpa. It is due for completion in 2008. Following the closure of the Mt Isa lead mine at the end of 2005, supply from the Black Star open cut mine increased with a total of 2.1 Mt of ore produced during its first full year of production. Output from Black Star will continue to increase in 2007 to ensure full utilisation of the concentrator. The George Fisher underground mine produced 2.6 Mt of ore in 2006, which was marginally higher than in 2005. Further improvements are planned for the mine during the second half of 2007 at a cost of \$26 million. The work will increase shaft hoisting capacity to its maximum infrastructure capacity of 3.1 Mtpa.

**Dugald River (Qld):** In December 2006 Zinifex Ltd completed a pre-feasibility study which indicated that development of a mine was viable. The study showed that annual production from the mine would be 200 kt of Zn, 40 kt Pb and 1.5 Mozs Ag over a 16 year mine life from a resource of 47.9 Mt at 12.1% Zn, 2.1% Pb and 44g/t Ag. Zinifex plans to spend \$25 million over 18 months on a full feasibility study with a mine development decision expected mid-2008. If developed, first production would probably occur in 2011. Pre-feasibility estimates put the cost of developing Dugald River at less than \$500 million.

**Rosebery (Tas):** Zinifex Ltd announced the likely discovery of a large new ore lens accessible from the upper levels of the mine and is spending \$19 million over the next three years on exploration at Rosebery, including infill drilling of the new lens in 2007. Ore has been mined at Rosebery for more than a century, including more than 70 years at the current site. Although Rosebery has had a mine life of between four and six years for many years, the new project is aimed at extending its life to at least 2018.

**Cannington (Qld):** Following an assessment of ground conditions in May 2006 at BHP Billiton's Cannington silver-zinc-lead mine, a US\$25 million program was undertaken in the second half of 2006 to improve safety conditions at the southern zone. This reduced production by approximately 20% throughout the period.

**Broken Hill – CML7 (NSW):** At the Rasp mine project, the Western Mineralisation, which is a previously unmined zinc lode, will be accessed by a 2.1 km, \$20 million decline that will take 12 months to complete. The decline will provide access for bulk samples and infill drilling for a feasibility study into a 750 ktpa operation. The resource estimate above 400 m is 5.6 Mt at 5.1% Zn, 3.8% Pb and 45g/t Ag. This increases to 10.1 Mt at 4.9% Zn, 3.5% Pb and 43g/t Ag, to a depth of 800 m. The project is based on an initial mine life of five to seven years during which time ore will be extracted from the upper 300 m of the Western Mineralisation, between 100 and 400 m depth. The deposit is offset at depth by a fault and repeated as the Centenary Mineralisation for which drilling by CRA in the 1980s outlined 6.7 Mt at 6% Zn, 2.3% Pb and 32g/t Ag.

**Angas (SA):** Terramin Australia released the final feasibility study for its \$64 million Angas zinc project located 46 km south east of Adelaide and 2 km from the South Australian town of Strathalbyn. Angas is forecast to produce 320 kt of zinc concentrate (52% Zn) and 125 kt of lead concentrate (50% Pb, 4.5% Cu, 450g/t Ag and 7g/t Au) over its seven-year life from a probable reserve of 2.34 Mt at 8.1% Zn, 3.1% Pb, 0.3% Cu, 33g/t Ag and 0.5g/t Au. Construction is to start after the land around the mine has been purchased and approval has been given for the mining and rehabilitation plan.

**Sulphur Springs (WA):** CBH Resources Ltd announced the ore reserves for a 1.25 Mtpa open-cut development have been calculated as 10 Mt at 3.5% Zn, 1.4% Cu and 17g/t Ag from a resource base of 13.8 Mt at 3.7% Zn, 1.4% Cu and 21g/t Au. Sulphur Springs is expected to produce from the open cut for eight years at an average rate of 75 ktpa of zinc concentrate grading 53% Zn and 65 ktpa of copper concentrate grading 25% Cu, after which it is planned that depth-extensions of the deposit will be mined below the open pit from underground.

**Beltana (SA):** Perilya Ltd announced it is developing the Beltana zinc mine as the first phase of its Flinders project. Beltana has a mineral reserve of 150 kt at 38.3% Zn for 57 kt of contained zinc.

The project will directly ship the high-grade zinc oxide ore to smelters in Asia. Contained zinc sales for 2007–08 are forecast at 15 kt, increasing to 20 kt in subsequent years. The company also plans to develop the Reliance, Moolooloo, Aristotle and Aroona2 deposits, located within 15 km of the Beltana operation.

**King Vol (Qld):** Kagara Zinc Ltd announced a 115% increase to the resource base at the King Vol deposit to 3.3 Mt at 14% Zn, 0.8% Cu, 1.1% Pb and 43g/t Ag, for a total of 459 kt of contained zinc. Kagara also reported increased resources for the nearby deposits of Mungana with 1.96 Mt at 14.4% Zn, 2.8% Cu, 2.2% Pb, 1.14g/t Au and 187g/t Ag, and Dry River South, which contains reserves of 1.051 Mt at 8.2% Zn, 2.9% Pb, 1% Cu, 69g/t Ag and 0.65g/t Au.

**Jaguar (WA):** Jabiru Metals Ltd announced that its Jaguar mine near Leonora is expected to produce concentrates containing around 33.6 kt Zn and 9.6 kt Cu (plus 0.9 Mozs Ag) per annum from the second quarter of 2007 from reserves of 1.6 Mt at 3.1% Cu, 11.7% Zn, 0.72% Pb and 120g/t Ag. Jabiru sourced the 350 ktpa processing plant it is using at Jaguar from Teck Cominco's Cadjebut operation in the Kimberly.

**Pillara (WA):** Teck Cominco Ltd is restarting operations at the Pillara mine in the Lennard Shelf in a 50/50 joint venture with Xstrata Plc. The Pillara mine has an anticipated mine life of four years at an annual production rate of 70 kt to 80 kt Zn and 15 kt Pb in concentrate.

**Hellyer (Tas):** Intec Ltd commenced commercial production of bulk zinc concentrate from the 10.9 Mt Hellyer tailings dam resource which contains 305 kt of zinc at an average grade of 2.8% along with quantities of lead, silver, gold and copper. The Intec Hellyer mill complex is a 1.5 Mtpa facility consisting of a grinding mill and flotation circuits. Base-case production is forecast at 65 ktpa of concentrate grading 40–43% Zn, 9.5% Pb and 170g/t Ag.



## PRODUCTION AND RESOURCE LIFE



Dragline removing overburden at the Blackwater mine, Queensland (BHP Billiton Mitsubishi Alliance)

## Production and Resource Life

Australia's production of major and other selected mineral resources, concentrates and metals for calendar year 2006 are presented in Table 6. The data, published by the Australian Bureau of Agricultural and Resource Economics (ABARE) on a quarterly basis, show that mineral commodity production increased significantly for rutile concentrates (up 31%), ilmenite concentrates (17%), manganese ores and concentrates (17%), zircon concentrates (15%), refined gold (11%), copper ores and concentrates (9%) and iron ore and pellets (5%). Mineral commodity production that declined included refined nickel (down 30%), uranium (20%), lead ores and concentrates (14%), refined lead (10%) and diamond (4%).

**Table 6. Australian production and exports of selected mineral products 2006.**

Commodity	Production	Exports	Export value \$ million
<b>Aluminium</b>			
Bauxite (Mt)	61.8	5.5	133
Alumina (Mt)	18.3	15	6 083
Aluminium (Mt)	1.9	1.5	5 464
<b>Coal</b>			
Black raw (Mt)	398		
Black saleable (Mt)	302	236	23 195
Brown (Mt 2005–06)	71		
<b>Copper</b>			
Ores and concentrates (kt)	2 969	1 561	4 079
Refined primary (kt)	429	284	2 504
<b>Diamond</b> (Mc)	29.3	29.3	614
<b>Gold</b>			
Mine production (t)	245		
Refined (t) (a)	379	349	8 862
<b>Iron and Steel</b>			
Ore and Pellets (Mt)	275	247	14 366
Iron and steel (Mt)	7.9	2.6	1 728
<b>Lead</b>			
Ores and concentrates (kt)	936	451	737
Refined (kt)	206	218	365
Bullion (kt)	118	121	259
<b>Manganese</b>			
Ores and concentrates (kt)	4.6	4.2	465
<b>Mineral sands</b>			
Ilmenite concentrates (kt)	2378	905	99
Rutile concentrates (kt)	232	231	192
Synthetic rutile (kt)	703	491	340
Titanium dioxide pigment (kt)	208	173	429
Zircon concentrates (kt)	492	487	446
<b>Nickel</b>			
Concentrate (kt Ni)	185		
Refined (kt)	165(b)	201	5 514(c)
<b>Uranium</b> (kt U <sub>3</sub> O <sub>8</sub> )	8.9	8.7	529
<b>Zinc</b>			
Ores and concentrates (kt)	2 554	1 831	2 386
Refined (kt)	464	356	1 411

## Notes for Table 6

Source: *Australian Mineral Statistics, ABARE, March quarter 2007*

t = tonnes; kt = 10<sup>3</sup>t; Mt = 10<sup>6</sup>t; Mc = 10<sup>6</sup> 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

ABARE reported that Australia's export earnings from mineral resources rose to \$101 billion (including petroleum of \$14.6 billion) in 2006, an increase of \$22.5 billion or 29% compared with 2005. The continued strong performance mainly reflected high prices for many of the major mineral resources (iron ore, coal, copper, zinc), largely as a result of increased demand from Asia. Based on Australian Bureau of Statistics (ABS) survey data new capital expenditure in 2005–06, in the mining and metal products industries was \$18.6 billion, the highest on record. This gives an indication, in aggregate terms of the pace and scale of developments in the minerals and energy sector, and was 135% higher than the average annual expenditure for the past 25 years (\$7.9 billion).

To sustain such growth and contribution to national economic performance in the medium and longer terms depends on new resources being 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 are provided in the commodity reviews above, as an indicator of resource life. It is important to note that these 'duration indicators' can change rapidly with significant changes in rates of production and/or major changes to resources. Iron ore, for example, shows how resource life can change markedly over a relatively short period. Increased production in response to growing demand from Asia is a major factor contributing to a 50% reduction in the duration of iron ore resources from 125 years in 1995 to around 67 years in 2006. In addition, the 20% reduction in EDR over the period is due to implementation of the JORC Code by the iron ore industry.

Resource life duration for gold (about 20 years at current rates of production), lead and zinc (both around 30 years), and diamond (about 7 years) are relatively low. Increases in the price of gold have contributed to increased expenditure on exploration for this commodity since 1980. However, despite a progressive increase in EDR of gold since the mid-1980s, there is still a need for ongoing successful exploration in the short and medium terms to ensure sufficient available resources to maintain gold as one of Australia's main exports.

There is a need for significant new discoveries of lead and zinc just to maintain production at current levels beyond the next 25 years, when almost all existing base metal mines will have closed. In this regard the focus is on discovery and development of new high quality, metallurgically attractive lead-zinc deposits.

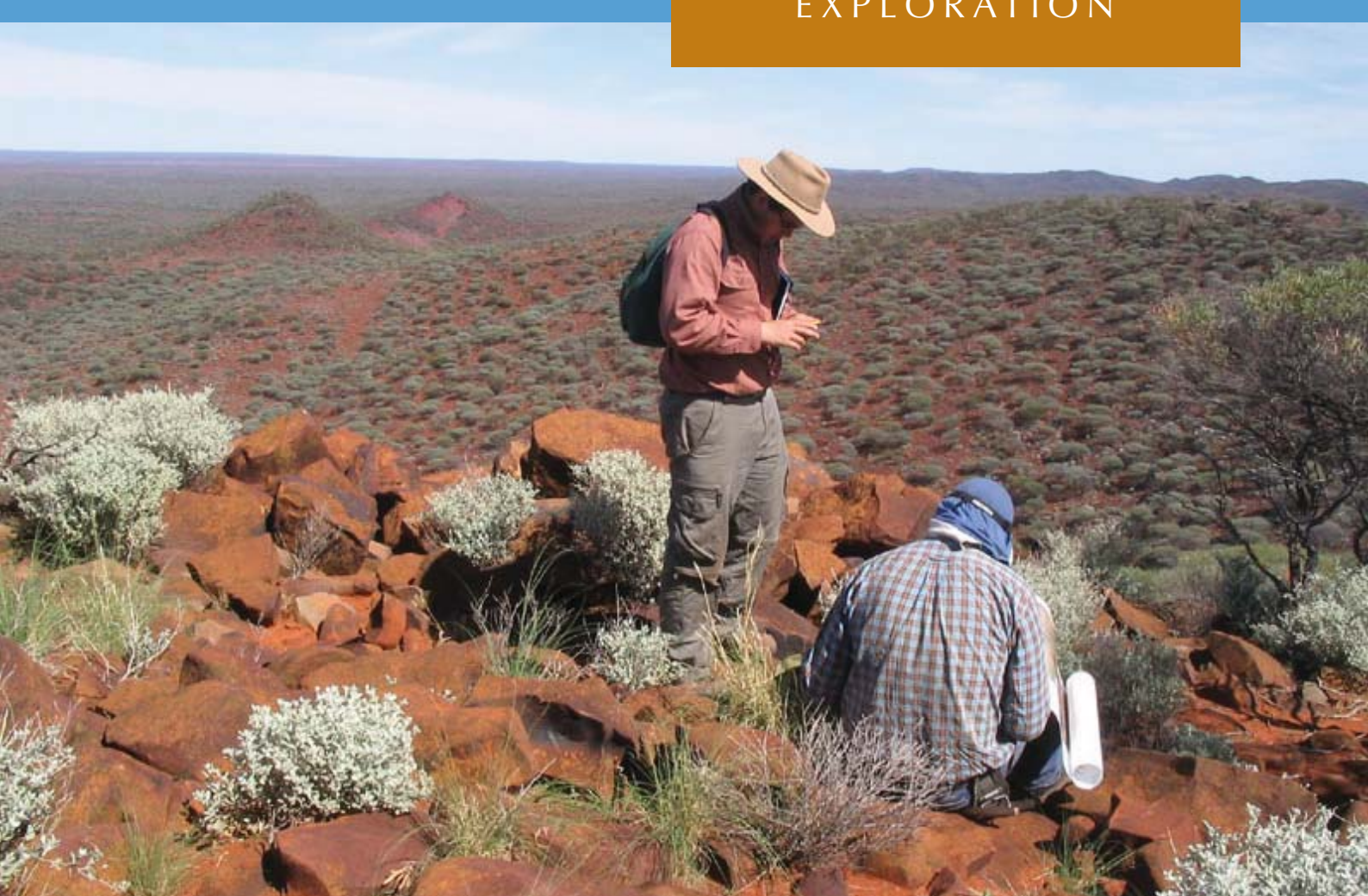
Table 7 presents a comparison of the AEDR/production ratios as assessed over a 10 year period. The assessment provides an indication of the length of time that mining of AEDR could continue at rates of production for each year. There is a markedly lower AEDR/production ratio for coal, iron ore, manganese ore and uranium, which are the net result of major increases in production and reassessment of resources.

**Table 7: Years of accessible economic demonstrated resources (AEDR) at the production level for the year (rounded to nearest 5 years)**

Commodity	1996	2006
Bauxite	70	90
Black coal	200	100
Brown coal	800	440
Copper	50	50
Diamond	5	10
Gold	15	20
Iron Ore	120	65
Lead	40	35
Manganese ore	60	30
Mineral sands		
ilmenite	70	75
rutile	80	70
zircon	50	50
Nickel	60	130
Silver	40	25
Uranium	130	75
Zinc	40	30



# EXPLORATION



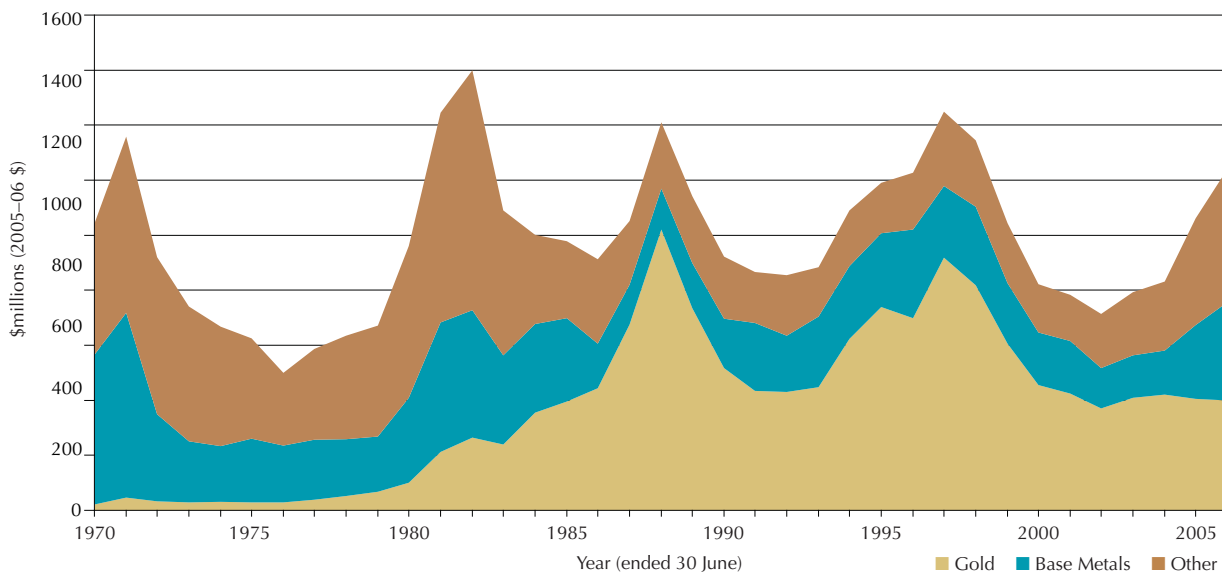
Iron ore exploration at Mount Weld, Western Australia (Midwest Corporation Ltd)



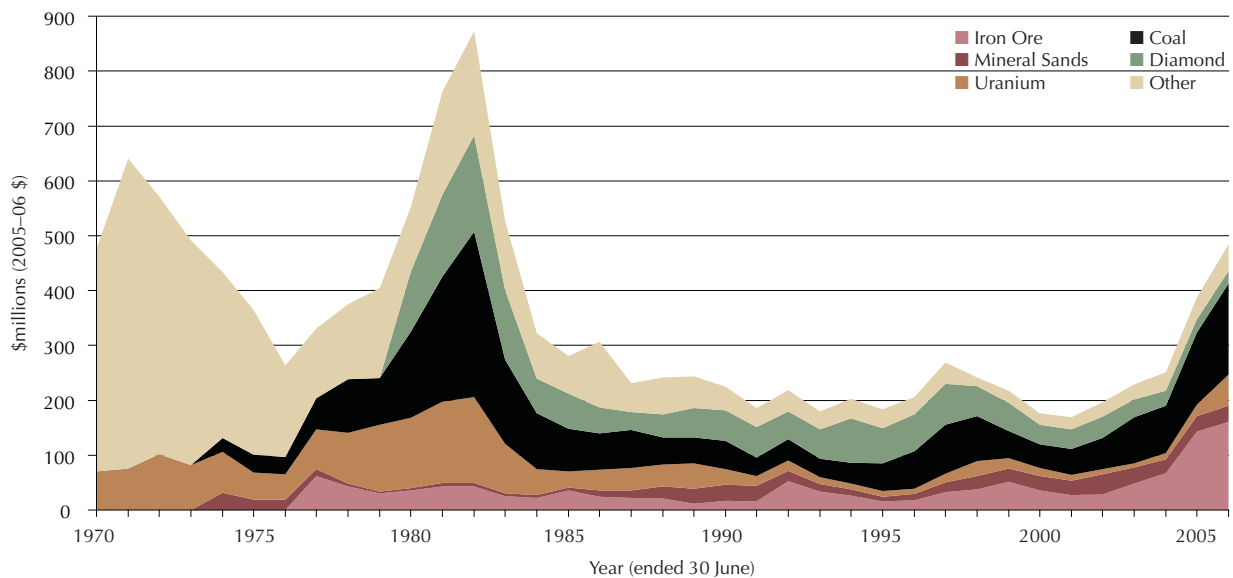
## Exploration

The ABS collects data on exploration expenditure in Australia. Figures 2 and 3 are based on ABS data, which have been deflated to produce a constant 2005–06 expenditure series. The figures are broken down by commodity and show trends in exploration expenditure since 1970. Figure 4 provides details of actual expenditure by commodity in dollars of the year, since 1992–93. Figure 5 shows the exploration expenditure by jurisdiction for the same period. Geoscience Australia produces an annual review of mineral exploration in Australia entitled Australian Mineral Exploration, which is based on public reports by companies and includes statistical data.

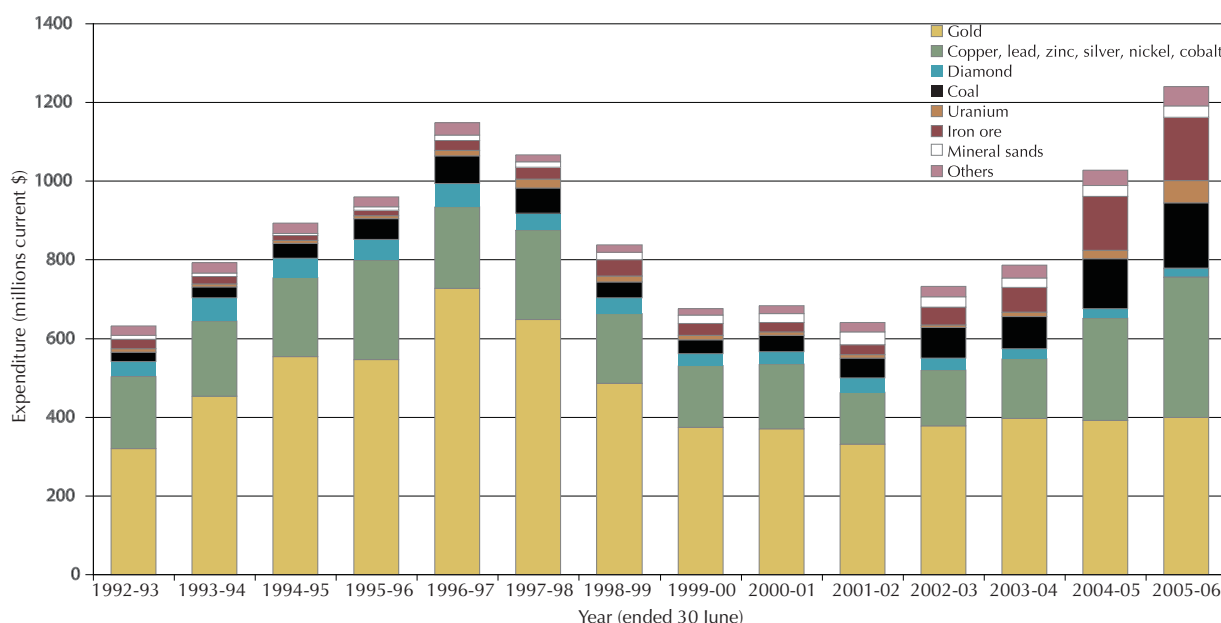
**Figure 2. Australian mineral exploration expenditures by commodity in constant 2005–06 dollars (Based on ABS data deflated by Consumer Price Index series).**



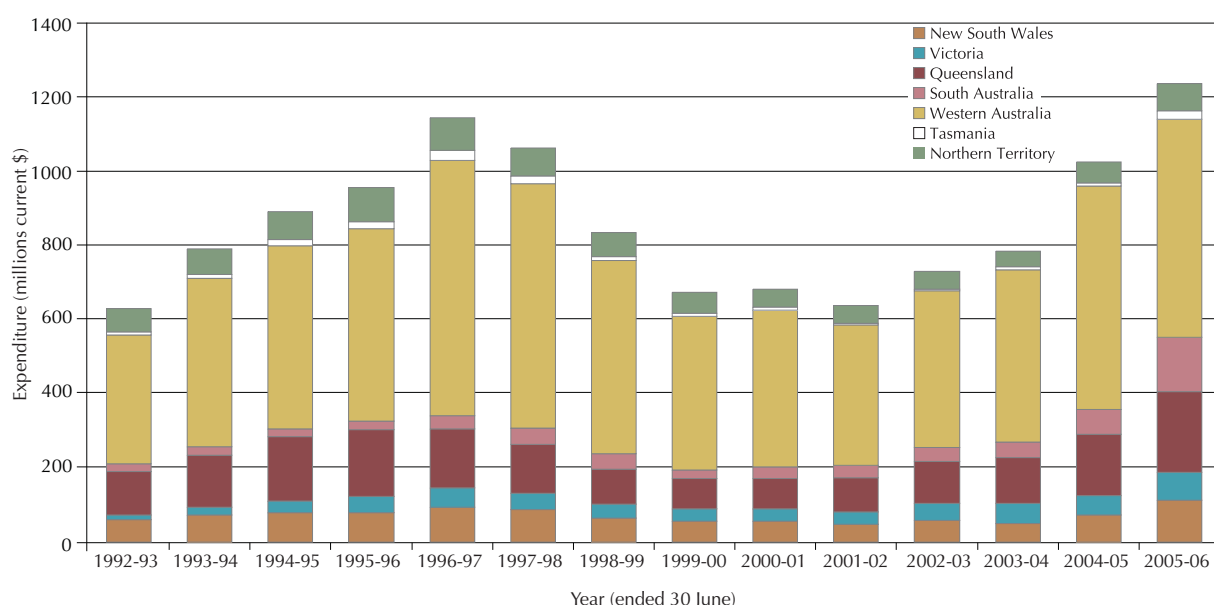
**Figure 3. Australian mineral exploration expenditures, excluding gold and base metals, in constant 2005–06 dollars (Based on ABS data deflated by Consumer Price Index series).**



**Figure 4. Australian mineral exploration spending by commodity (Source: ABS).**



**Figure 5. Australian mineral exploration spending by State (Source: ABS).**



In 2006, exploration expenditure rose by 29% to \$1463.9 million. This growth reflects increased prices for many commodities on the back of anticipated strong and growing demand, particularly from China.

While gold remained the predominant target in 2006 its share of total spending fell again to 29%. Gold exploration spending totalled \$429.8 million in 2006, an increase of more than \$45 million (Table 8). The base metal group had a substantial increase in its share of total spending to 29% with actual spending rising by \$105.7 million to \$426.1 million. The growth in base metals was driven by substantial increases in zinc-lead-silver exploration which more than doubled to \$100.7 million and copper which rose by 68% to \$177.5 million. In contrast, spending on nickel exploration fell by \$20.2 million to \$147.9 million. Uranium exploration spending also more than doubled in 2006 rising from \$37.7 million to \$80.7 million. Iron ore exploration rose by \$72.5 million to \$224.7 million and its share of total spending increased to 15.3% in response to continuing strong international demand. Similarly coal exploration grew strongly rising from \$145.6 million to \$198.7 million in the year.

All States and the Northern Territory recorded increases in 2006. Western Australia remained dominant with an increase of \$71.5 million in 2006 to \$685.3 million. This growth was, however, insufficient for the State to maintain its share of national spending which fell to 47% from 54% in 2005 (Table 9). South Australia recorded the largest dollar increase in spending and increased its share of national spending to 13.1%.

**Table 8: Australian mineral exploration expenditure by commodity, 2005 and 2006**  
(Source: ABS)

Commodity	Exploration Spending (\$ million)		Change (\$ million)	Proportion of Australian Total Exploration Spending		Change % points
	2005	2006		2005	2006	
Gold	384.1	429.8	45.7	33.8	29.4	-4.5
Copper	105.8	177.5	71.7	9.3	12.1	2.8
Zinc, lead, silver	46.5	100.7	54.2	4.1	6.9	2.8
Nickel, cobalt	168.1	147.9	-20.2	14.8	10.1	-4.7
Base Metals	320.4	426.1	105.7	28.2	29.1	0.9
Diamond	22.8	27.8	5.0	2.0	1.9	-0.1
Coal	145.6	198.7	53.1	12.8	13.6	0.8
Iron Ore	152.2	224.7	72.5	13.4	15.3	2.0
Mineral Sands	30.1	31.3	1.2	2.6	2.1	-0.5
Uranium	37.7	80.7	43.0	3.3	5.5	2.2
Others	43.2	45.3	2.1	3.8	3.1	-0.7

**Table 9: Australian mineral exploration expenditure by State, 2005 and 2006** (Source: ABS)

Commodity	Exploration Spending (\$ million)		Change (\$ million)	Proportion of Australian Total Exploration Spending		Change % points
	2005	2006		2005	2006	
Western Australia	613.8	685.3	71.5	54.0	46.8	-7.2
Queensland	184.9	252.1	67.2	16.3	17.2	0.9
New South Wales	91.3	130.3	39.0	8.0	8.9	0.9
Northern Territory	68.6	85.4	16.8	6.0	5.8	-0.2
Victoria	65.5	82.2	16.7	5.8	5.6	-0.2
South Australia	99.4	191.4	92.0	8.8	13.1	4.3
Tasmania	12.7	27.8	15.1	0.9	1.9	1.0

## Exploration Outcomes

The increase in exploration activity saw strong growth in the number of reported intersections of mineralisation and several new discoveries. Indicative of the more significant announcements during the year were about Gullivers and Cooljarloo North (mineral sands), Saxon (nickel), Tekapo (gold-copper), Tandarra (gold), Cuttaburra (base metals), Swan (copper-gold-uranium), Rocklands (copper) and Tropicana (gold). Ongoing exploration also resulted in increases in resources in many known deposits.

Responding to world demand there was substantial activity in the iron ore sector with new resources and drilling results released for many smaller deposits and prospects. Similarly uranium exploration surged and the number of new companies with a focus on uranium is likely to ensure spending continues to grow.

Commentaries on exploration for individual commodities are under the review of resources for each commodity in this review.

### Outlook for Exploration

Both world and domestic mineral exploration levels grew strongly in 2006. The continuing high metal prices, particularly for the base metals, and the sustained higher gold price levels remain conducive to greater exploration activity in 2007. The strong growth in the Chinese economy continues to drive high levels of demand for many commodities and is expected to contribute to ongoing strong exploration spending. Overall, the outlook for exploration is sound and further growth in exploration expenditure can be expected.

### Exploration Stage

ABS reports statistics on spending on exploration for new deposits and for the further delineation and/or extension of known mineralisation that has resources delineated. Spending is classified as being for the search for new deposits until there has been a JORC Code resource estimate of any classification prepared. Subsequent spending on exploring that mineralisation would be classified as further delineation or extension of a deposit.

ABS survey data of spending showed that, nationally, 37% of spending was on exploration for new deposits. Western Australia (46%) had the highest proportion of its exploration directed to the search for new deposits while New South Wales had the lowest at 25%. The national share of exploration for new deposits is slightly lower than the Metals Economic Group (MEG) world survey of non-ferrous minerals exploration budgets for 2006 which found that 38% of exploration budgets in Australia was for grassroots exploration.

### Exploration Drilling

ABS reported that exploration drilling totalled 6.837 million metres, an increase of 53,000 metres. A reduction of 165,000m occurred in drilling in search of new mineralisation with 2.62 million metres drilled (38% of all exploration drilling).

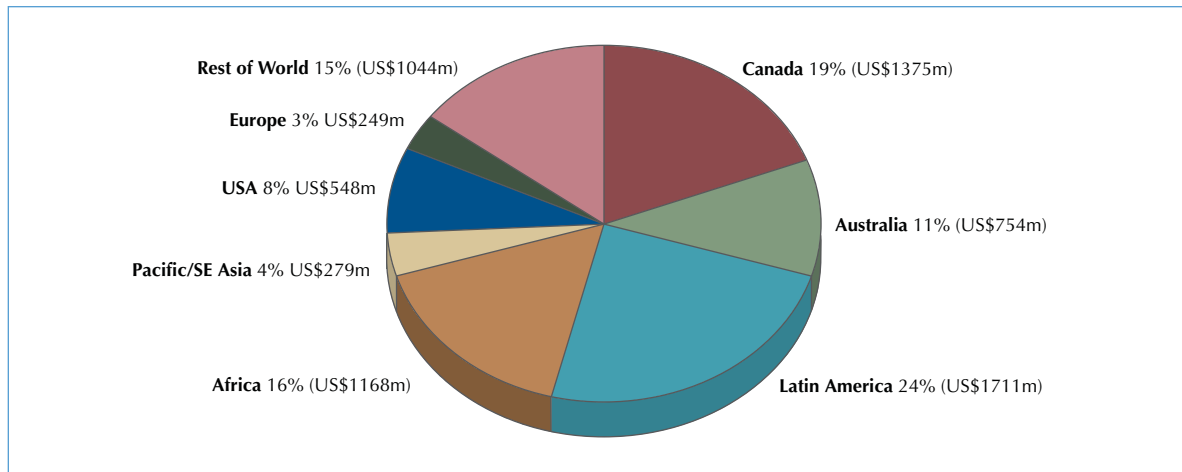
Some 75 initial public offerings on the Australian Stock Exchange in 2006 were fully or partially for exploration in Australia. An estimated \$350 million was raised by these companies for Australian exploration.

### World Exploration

The MEG survey of world non-ferrous mineral exploration budgets for 2006 reported an increase of 47% to an estimated record total budget of US\$7.5 billion. Of this, US\$753.5 million was directed to exploration in Australia, the highest since the peak year of 1997. However, Australia's share of global non-ferrous mineral exploration budgets fell to 10.6%, the lowest yet recorded. Australia retained its position as the country with the second highest share of budgets after Canada (19%) (Fig. 6).

According to the MEG survey, 53.8% of the 2006 non-ferrous mineral exploration budgets for Australian-based companies was for exploration in Australia. The survey included 330 companies with non-ferrous exploration budgets of more than US\$100,000 that were exploring in Australia, an increase of 22 over 2005. Budgets for Australian non-ferrous mineral exploration included: gold (US\$373.9 million), base metals (US\$292.5 million) and diamonds (US\$21.8 million).

**Figure 6. Distribution of world non-ferrous mineral exploration budgets, 2006**  
(Source: Metals Economics Group).



### 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, over the continental shelf three nautical miles beyond the territorial baseline of the States and territories. The administration of the Act is shared between the Commonwealth and the States and the Northern Territory. Applications for a mineral exploration licence (MEL) are made to the Designated Authority, usually the State or Territory Minister responsible for mining. The initial term of a licence is four years and it may be renewed for three two year periods subject to satisfactory performance of licence conditions.

A total of 76 offshore MEL applications have been received since February 1990. At the end of 2006 there were two active licences:

1. **T-2-MEL.** Van Dieman Mines is investigating the viability of a previously identified tin deposit in Ringarooma Bay in north east Tasmania.
2. **WA-31-MEL.** A joint venture is exploring for diamonds in the Joseph Bonaparte Gulf in the north west of Australia. To date no diamonds have been discovered in Commonwealth waters, however, gem quality diamonds have been discovered adjacent to the Berkeley and Ord Rivers in State waters.

An **Australian Offshore Minerals Locations** map that shows mineral occurrences and deposits within Australia's 200 nautical mile exclusive economic zone and extended continental shelf is available from the Sales Centre at Geoscience Australia. The Australian Offshore Mineral Locations data can be viewed online by using Geoscience Australia's **Australian Marine Spatial Information System** (AMSIS).



# Appendix 1

## Abbreviations and Acronyms

**ABARE** Australian Bureau of Agricultural and Resource Economics

**ABS** Australian Bureau of Statistics

**A\$** Australian dollar (where not stated, assume Australian currency)

**AEDR** accessible economic demonstrated resources

**AIMR** Australia's Identified Mineral Resources

**BRS** Bureau of Resource Sciences

**c** carat

**cpht** carats per hundred tonne

**CSIRO** Commonwealth Scientific and Industrial Research Organisation

**EDR** economic demonstrated resources

**GIS** geographical information system

**g** grams

**g/t** grams per tonne

**GL** gigalitre

**Gt** gigatonne

**IAEA** International Atomic Energy Agency

**JORC** Joint Ore Reserve Committee – *Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves*

**kg** kilogram

**km** kilometre

**kt** kilotonne (thousand tonnes)

**ktpa** kilotonne per annum

**L** litre

**lbs** pounds

**m** metre

**m<sup>3</sup>** cubic metre

**Mc** million carats

**MEL** mineral exploration licence

**ML** million litres

**MLbs** million pounds

**mm** millimetre

**Mozs** million ounces

**Mt** million tonnes

**Mtpa** million tonnes per annum

**MW** megawatt

**na** not available

**NSW** New South Wales

**NT** Northern Territory

**OECD/NEA** Organisation for Economic Cooperation and Development/Nuclear Energy Agency

**ozs** ounces

**PDR** paramarginal demonstrated resources

**PGM** platinum-group metals

**ppm** parts per million

**Qld** Queensland

**RAR** reasonably assured resources

**SA** South Australia

**SDR** subeconomic demonstrated resources

**t** tonne

**Tas** Tasmania

**tpa** tonnes per annum

**U** uranium

**U<sub>3</sub>O<sub>8</sub>** uranium oxide

**USA** United States of America

**USGS** United States Geological Survey

**US\$** United States of America dollar

**Vic** Victoria

**WA** Western Australia

**\$1 M** 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 resources, land-access, land-use and conservation. Results of resource assessment can be used also to set priorities for exploration and mineral potential is an important input to decisions 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, particularly for commercial reporting for individual deposits.

Several editions of an industry code for reporting resources in individual deposits have been published, the most recent being the 2004 edition entitled 'Australasian Code for Reporting of Exploration Results, 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 national assessments of Australia's mineral resources

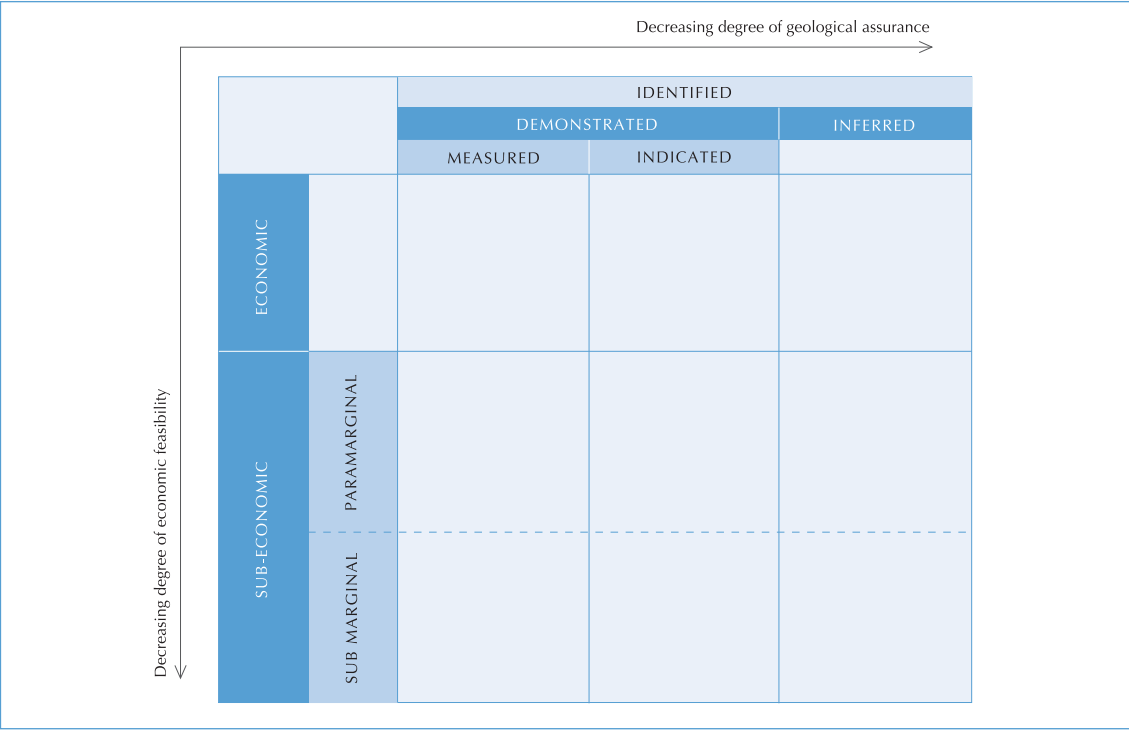
#### CLASSIFICATION PRINCIPLES

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.

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 used by Geoscience Australia 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 drill holes, 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 could be produced 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'.
- (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 outlined in (c) above.
- (iv) *Allowances (deductions) for losses due to mining and milling*

For resource categories of the National Scheme, allowances for losses due to mining and milling are the same as those for corresponding categories in the JORC Code. The allowances for losses, which apply to all minerals except coal and uranium, are summarised as follows:

National scheme	JORC scheme	Mining losses	Milling losses
<b>Measured resources</b>	Proved Ore Reserves	deducted	not deducted – but are considered in assessing economic viability
	Measured Mineral Resources	not deducted	not deducted
<b>Indicated resources</b>	Probable Ore Reserves	deducted	not deducted – but are considered in assessing economic viability
	Indicated Mineral Resources	not deducted	not deducted
<b>Inferred resources</b>	Inferred Resources	not deducted	not deducted

For coal, different terms are used – ‘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.

Uranium resources are reported in the categories of the OECD Nuclear Energy Agency & International Atomic Energy Agency classification scheme. Losses due to mining and milling are deducted from resources in all categories. These estimates are referred to as ‘Recoverable resources’ and reported under the corresponding categories in the National Scheme.

- (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.



## References

- BMR, 1976. BMR adopts new system of resource classification. *Australian Mineral Industry Quarterly*, 28(1), 11–13.
- BMR, 1984. BMR refines its mineral resource classification system. *Australian Mineral Industry Quarterly*, 36(3) 73–82.
- JORC, 2004. Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (the JORC Code). Report of the joint committee of the Australasian Institute of Mining & Metallurgy, Australian Institute of Geoscientists and Minerals Council of Australia, 20pp.
- King, H.F., McMahon, D.W. and Bujtor, G.J., 1982. A guide to the understanding of ore reserve estimation. *Australasian Institute of Mining and Metallurgy*, Melbourne, 21 pp.
- McKay, W.J., Miezeitis, Y., Exon, N.F. and Sait, R., 2005. Australia's Offshore Minerals: an overview. In *Deep Blue Minerals – towards a sustainable marine minerals industry: extended abstracts*. CSIRO Exploration and Mining Report P2005/135, eds C. J. Yeats and T.F. McConachy, 9-14.
- USBM/USGS, 1980. Principles of a resource/reserve classification for minerals. *US Geological Survey Circular 831*, 5 pp.

## Appendix 3

### Staff and Commodity Responsibilities: AIMR 2007 and Related Projects

#### MINERAL RESOURCES AND ADVICE GROUP

Name	Telephone	Email	Commodity
Ian Lambert (Leader)	+ 61 2 6249 9556	ian.lambert@ga.gov.au	

#### RESOURCES AND ADVICE PROJECT

Name	Telephone	Email	Commodity
Aden McKay (Leader)	+ 61 2 6249 9230	aden.mckay@ga.gov.au	Uranium, tin, tungsten, vanadium, magnesite, mineral potential
Bill McKay (Executive Officer OEMD)	+ 61 2 6249 9003	bill.mckay@ga.gov.au	Bauxite-alumina-aluminium
Yanis Miezitis	+ 61 2 6249 9523	yanis.miezitis@ga.gov.au	Nickel, cobalt, PGM, mineral sands, thorium, mineral potential, decision support
Keith Porritt	+ 61 2 6249 9479	keith.porritt@ga.gov.au	Copper, lead, zinc, silver, diamond, decision support
Leesa Carson	+ 61 2 6249 9872	leesa.carson@ga.gov.au	Uranium, shale oil, tantalum, niobium, lithium, phosphate
Ron Sait	+ 61 2 6249 9550	ron.sait@ga.gov.au	Coal, coal bed methane, iron ore, manganese, offshore mineral exploration
Michael Sexton	+ 61 2 6249 9672	michael.sexton@ga.gov.au	GIS, IM and Project Data Support

#### MINERAL EXPLORATION PROMOTION PROJECT

Name	Telephone	Email	Commodity
Mike Huleatt (Leader)	+ 61 2 6249 9087	mike.huleatt@ga.gov.au	Gold, exploration expenditure

### **Postal Address**

Geoscience Australia  
GPO Box 378  
Canberra ACT 2601  
AUSTRALIA

### **Location**

Cnr Jerrabomberra Ave and Hindmarsh Drive  
Symonston ACT 2600  
AUSTRALIA

### **Internet**

[www.ga.gov.au](http://www.ga.gov.au)

### **ABN**

80 091 799 039

### **Credits**

Geoscience Australia staff, outside organisations and individuals provided the photos and images reproduced in this publication. BHP Billiton Ltd, Groote Eylandt Mining Company, BHP Billiton Mitsubishi Alliance, Midwest Corporation Ltd, Aquila Resources Ltd, Mount Gibson Iron Ltd, Kalgoorlie Consolidated Gold Mines Ltd, OM Holdings Ltd, MetalsX Ltd and Heathgate Resources Ltd gave approval to use images shown in 2007.