



Australian Government
Geoscience Australia

AUSTRALIA'S IDENTIFIED MINERAL RESOURCES 2005



Australian Government Geoscience Australia

Industry, Tourism and Resources Portfolio

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

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

FRONT COVER: Iron ore train from West Angelas mine, Western Australia (Pilbara Iron Pty Ltd)

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

Foreword

Geoscience Australia provides information on the nation's future capacity to produce mineral resources. *Australia's Identified Mineral Resources* is an annual nation-wide assessment of Australia's ore reserves and mineral resources, 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 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. Expansions in mine production of coking coal, iron ore, uranium and other commodities continued in 2004 and the resources sector overall continued to contribute to Australia's prosperity – economically, environmentally and socially. In 2004–05, over 35% of the country's total exports with an estimated worth of \$65 billion, came from the resources sector.

The sustainability of the minerals industry and its major contributions to the nation's prosperity is inexorably linked to effective exploration, leading to discovery and development of new ore deposits. In turn, 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 regional geoscience data to reduce risks in identifying exploration targets in prospective frontier regions. It is in such regions, which are characterised by extensive barren cover, that the best potential exists for the large deposits that are of interest to major mining companies. Australia's decline from first to fifth in global exploration expenditure over the past five years is largely a reflection of the paucity of information for these regions, which has been influencing major companies to explore in other parts of the world where they consider exploration risks are lower.

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



NEIL WILLIAMS

Chief Executive Officer
Geoscience Australia

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Summary

Australia's economic demonstrated resources (EDR) of the following mineral commodities increased during 2004 – bauxite, black coal, copper, gold, iron ore, ilmenite, lead, manganese, rare earth elements, tantalum, tin, uranium and zinc. EDR of cobalt, diamonds (both gem and industrial), lithium, phosphate, rutile, silver, tungsten and zircon decreased during the year. EDR for brown coal, magnesite, molybdenum, nickel, niobium, platinum group metals, shale oil, and vanadium remained at levels similar to those reported in 2003.

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. Newly delineated resources of 1 256 t added to gold's total national inventory, with growth in all east coast mainland states and South Australia. A few mining companies re-estimated ore reserves and mineral resources more conservatively for some commodities to comply with the requirements of the *Australasian Code for Reporting of Mineral Resources and Ore Reserves* (JORC Code).

World ranking: Australia's EDR of zinc, lead, nickel, mineral sands (rutile and zircon), tantalum and uranium 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-use restrictions that prevent mining. In particular, this is the case for some mineral sands and uranium deposits.

Resources and current rates of mine production: Ratios of AEDR to current mine production provide rough estimates for the resource life. 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.

The resource lives for gold (an average of 22 years at current rates of production), lead (around 35 years) and zinc (around 30 years) are amongst the lowest. There is a need for ongoing successful exploration in the short and medium terms to maintain gold as one of Australia's main export commodities. Similarly, new discoveries of large lead and zinc deposits are needed in the not too distant future to sustain production of these commodities at current levels, given that almost all existing base metal mines will have closed, and also that there is typically a period of about 10 years between initial discovery of a deposit and commencement of production for large base metal mines.

Mineral exploration: Mineral exploration expenditures in Australia rose by 7.4% to \$786.7 million in 2003–04. Spending for calendar year 2004 rose strongly by 24% to \$920.6 million with expenditure of \$511.9 million in the second half of 2004 contrasting with \$384.6 million in the equivalent period in 2003.

While gold remained the predominant target in calendar year 2004, its share of total spending fell below 50% to \$414 million. The base metal group increased its share of total spending to 22.5% – \$207.4 million, an increase of \$72.7 million.

ABS, for the first time, reported 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 compliant resource estimate of any classification prepared. Thereafter spending on exploring that mineralisation is classified as further delineation or extension of a deposit. Nationally 39% of exploration spending was directed at the search for new deposits. Tasmania had the highest proportion of exploration in this category of any jurisdiction with 54.7% of its spending whereas the Northern Territory had the lowest at 31.3%.

Both world and domestic mineral exploration levels grew strongly in 2004. Higher metal prices, particularly for the base metals, and sustained higher price levels for gold are conducive to greater exploration activity in 2005. Demand from China is expected to continue to influence trends in both prices and exploration, particularly for base metals, iron ore, coal and uranium.

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 Government policy decisions relating to the minerals sector and sustainable development of mineral resources. Data on Australia's resources of coal and other energy minerals were used in preparation of the Government's White Paper on energy entitled '*Securing Australia's Energy Future*', released in 2004. In 2005, information on the amount and location of major mineral resources was utilised by the Infrastructure Taskforce to advise the Government on bottlenecks that impede the full realisation of Australia's export opportunities.

In *Australia's Identified Mineral Resources 2005*, estimates of Australia's mineral resources of all major and several minor mineral commodities are reported for 2004 (Table 1). The estimates are based on published and unpublished data available to Geoscience Australia up to the end of December 2004. 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 2005 also provides information and analysis on mineral exploration expenditures in Australia for 2003–04, and puts these into perspective by comparisons with exploration expenditures (in real terms) over the preceding 33 years.

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

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

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

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

EDR/production, AEDR/production and OR/production ratios provide information on the resource life of Australia's mineral commodities based on production rates at the time of assessment. Each of these has deficiencies as an indicator of resource life: OR/production is a more conservative (and for some commodities very much more conservative) indicator 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.

TABLE 1. Australia's resources of major minerals and world figures as at 31 December 2004.

Commodity	Units	Australia							World	
		Demonstrated Resources			Inferred Resources (a)	Accessible EDR ^(b) (AEDR)	JORC Reserves ^(c) (% of AEDR)	Mine Production ^(d) 2004	Economic Demon- strated Resources ^(e)	Mine Pro- duction ^(f) 2004
		Economic (EDR)	Subeconomic							
			Para- marginal	Sub- marginal						
Antimony	kt Sb	80	31	52	54	80	46.3 (58%)	–	1 800	112
Asbestos Chrysotile ore Crocidolite fibre	kt	–	46.2	–	75	–	–	–	large	2.3 ^(g)
	kt	–	0.4	–	2	–	–	–	large	
Bauxite	Gt	5.7	0.6	1.4	1.1	5.3	2.1 (40%)	0.057	23	0.156 ^(e)
Black coal in situ recoverable	Gt	57.4	5.1	12.6	85.5					
	Gt	40.4	2.7	8.7	52.7	40.3	13.1 ^(h) (33%)	0.375 ⁽ⁱ⁾	743 ^(j)	4.1 ^{(j)(k)}
Brown coal in situ recoverable	Gt	41.7	43.4	18.1	112					
	Gt	37.5	39.0	16.3	100.8	30.0	2.1 ^(h) (7%)	0.068 ^(j)	156 ^(j)	0.84 ^(j)
Cadmium	kt Cd	65.5	9.5	19.4	1.3	65.5	53.9 (82%)	0.35	569	17.2
Cobalt	kt Co	1 253	219	140	1 395	1 253	403 (32%)	4.55	6 798	44.5
Copper	Mt Cu	42.1	3.6	1.3	29.9	42.1	19.6 (47%)	0.854	490	14.5
Diamond gem & near gem industrial	Mc	53.4	201.5	0.2	15.9	53.4	51.9 (97%)	10.1	–	81.8
	Mc	55.6	209.7	0.3	16.6	55.6	54 (97%)	10.5	580	70.0
Fluorine	Mt F	–	0.2	23.7	21.3	–	–	–	112 ^(l)	2.4
Gold	t Au	5 589	1 102	107	4 058	5 570	3 330 (60%)	259	42 000	2 489
Iron ore	Gt	14.6	0.2	1.9	16.9	14.6	4.6 (32%)	0.234	160.0	1.25
Lead	Mt Pb	22.9	2.9	9.3	21.6	22.9	9.9 (43%)	0.677	70	3.15
Lithium	kt Li	170	54	26	7	170	145 (85%)	0.59	4 110	14.5 ^(m)
Magnesite	Mt MgCO ₃	344	22	35	931	344	37.5 (11%)	0.586	7 629	12.3 ^(m)
Manganese ore	Mt	133	28	167	135	133	95 (71%)	3.4	1 175	25
Mineral sands Ilmenite Rutile Zircon	Mt	217.2	51	0.1	119	180.7	42.4 (23%)	1.93	1 088	8.97
	Mt	20.2	12	0.1	29	14.5	3.85 (27%)	0.162	52	0.4 ^(m)
	Mt	30	19	0.1	33	21.8	5.7 (26%)	0.441	74	1.07
Molybdenum	kt Mo	0.4	6.3	3.7	411	0.4	0 (–)	–	8 600	139
Nickel	Mt Ni	22.6	2.8	1.3	19.5	22.6	7 (31%)	0.187	61.8	1.4
Niobium	kt Nb	194	115	0	1 838	194	21 (11%)	⁽ⁿ⁾	4 565	29.8
Phosphate rock	Mt	86	981	–	1 125	86	86	0.884 ^(o) 0.586 ^(p)	18 000	138
PGM (Pt,Pd,Os,Ir,Ru,Rh)	t metal	18.5	152.9	5.4	65.2	14.6	0.6 (4%)	1.04	71 000	n/a ^(q)
Rare earths (REO & Y ₂ O ₃)	Mt	0.5	2	12.2	12	0.1	0 (–)	–	89	0.1
Shale oil	GL	4.6	202	3 719	41 425	4.6	4.6 (100%)	<0.1	95 885 ^(r)	n/a ^(s)
Silver	kt Ag	41.4	17.6	16.9	33.5	41.4	26.0 (63%)	2.237	280	19.5
Tantalum	kt Ta	53	32	0.2	69	53	40.3 (76%)	0.6 ^(t)	56	1.11
Tin	kt Sn	163	95	134	290	163	64 (39%)	0.8	6 100	250
Tungsten	kt W	4.6	31.8	27.7	56.7	4.6	2.5 (54%)	0	2 900	60
Uranium	kt U	701	13	33	396	627	447 (71%)	8.98	1 743 ^(u)	39.60 ^(v)
Vanadium	kt V	0	779	1 807	2 475	0	0 (–)	0	13 000	44
Zinc	Mt Zn	41.0	8.5	14.9	25.2	41.0	21.3 (52%)	1.334	222	9.1

See notes on following page.

Notes for Table 1

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

- (a) Total inferred resources in economic, sub-economic and undifferentiated categories.
- (b) Accessible EDR (AEDR) is the portion of total EDR that is accessible for mining. AEDR does not include resources which are inaccessible for mining because of environmental restrictions, government policies or military lands.
- (c) Joint Ore Reserves Committee (JORC) Proven and Probable Ore Reserves as stated in company annual reports and reports to Australian Stock Exchange.
- (d) Sources: Australian Bureau of Agricultural and Resource Economics (ABARE).
- (e) Sources: Geoscience Australia for Australian figures, USGS Mineral Commodities Summaries for other countries.
- (f) World mine production for 2004, mostly USGS estimates.
- (g) Includes chrysotile production.
- (h) Black and brown coal reserves include both JORC reserves and Geoscience Australia estimated reserves for operating mines that do not publish JORC reserves.
- (i) Raw coal.
- (j) Geoscience Australia estimate.
- (k) Saleable coal.
- (l) Excludes Morocco and USA.
- (m) Excludes USA.
- (n) Not reported by mining companies.
- (o) Source: WMC Resources Ltd 2004 Annual Report (di-ammonium phosphate 647 862 t; mono-ammonium phosphate 236 059 t).
- (p) Source: Phosphate Resources Ltd Annual Report 2003 (518 500 dry tonnes of rock shipped; 67 237 dry tonnes of dust shipped).
- (q) Latest production figure is 358 t for 2003 from USGS Mineral Commodities Summaries 2004.
- (r) Source: WEC Survey of Energy Resources for 1999.
- (s) Latest production figure is 0.47 GL from the WEC Survey of Energy Resources for end 2002.
- (t) Tantalum production from company data.
- (u) Source: OECD/NEA & IAEA (2004). Compiled from the most recent data for resources recoverable at <US\$40/kg U. Data for USA is not available for this category.
- (v) Source: WMC Resources Ltd Annual Report for 2004.

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 1975–2004 (Fig. 1). These changes for each commodity can be attributed to one, or a combination of the following factors:

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

Past trends and changes in EDR for a number of Australia's major mineral commodities are discussed below. It is notable that resources levels for major commodities like black coal, iron ore and base metals have plateaued.

Black Coal

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

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

Bauxite

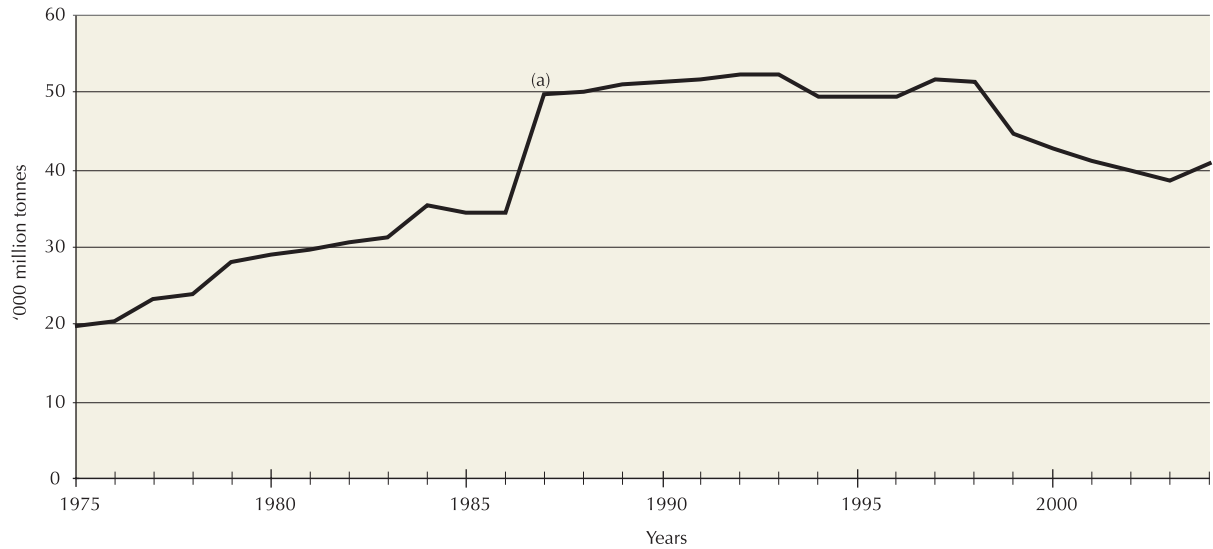
Increases in bauxite EDR in 1989 resulted from delineation of additional resources in deposits on Cape York Peninsula ('b' on Fig. 1). Decreases in bauxite EDR in 1992 were due to re-classification of some resources within deposits on Cape York Peninsula so as to comply with requirements for the JORC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

Iron Ore

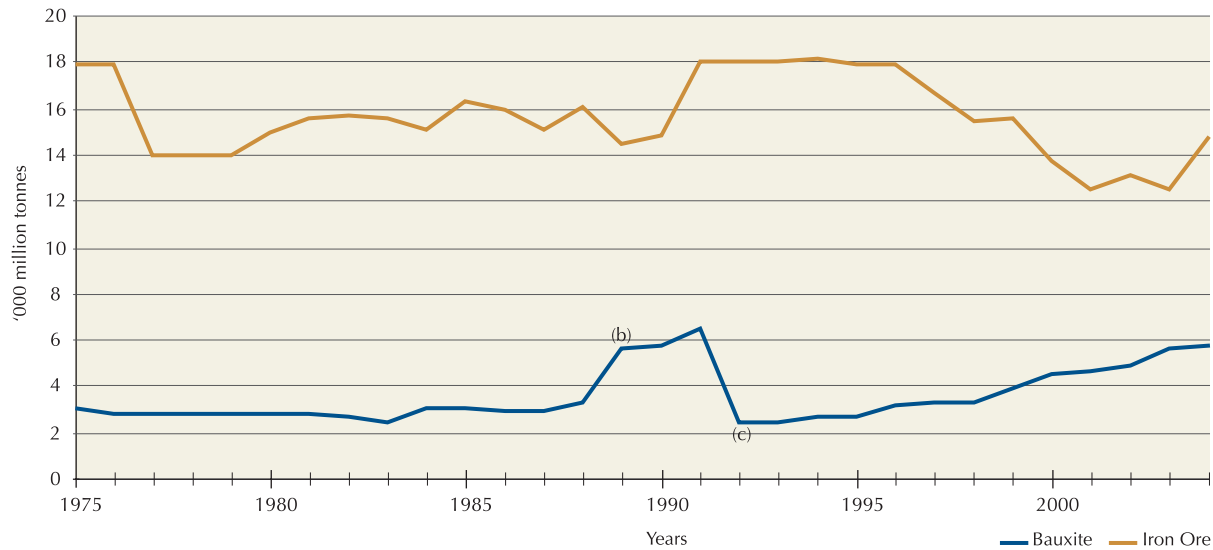
EDR for iron ore has declined since 1996 due to the combined impacts of mining companies re-estimating ore reserves and mineral resources more conservatively so as to comply with requirements of the JORC Code, and increased rates of mine production.

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

Black Coal (recoverable)



Bauxite, Iron Ore



Gold

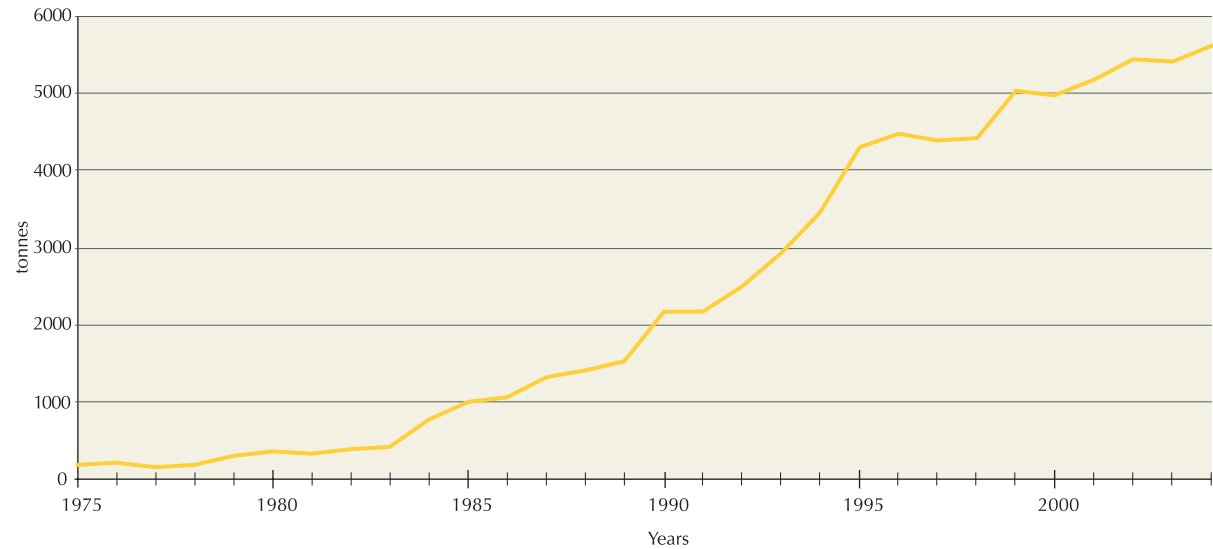
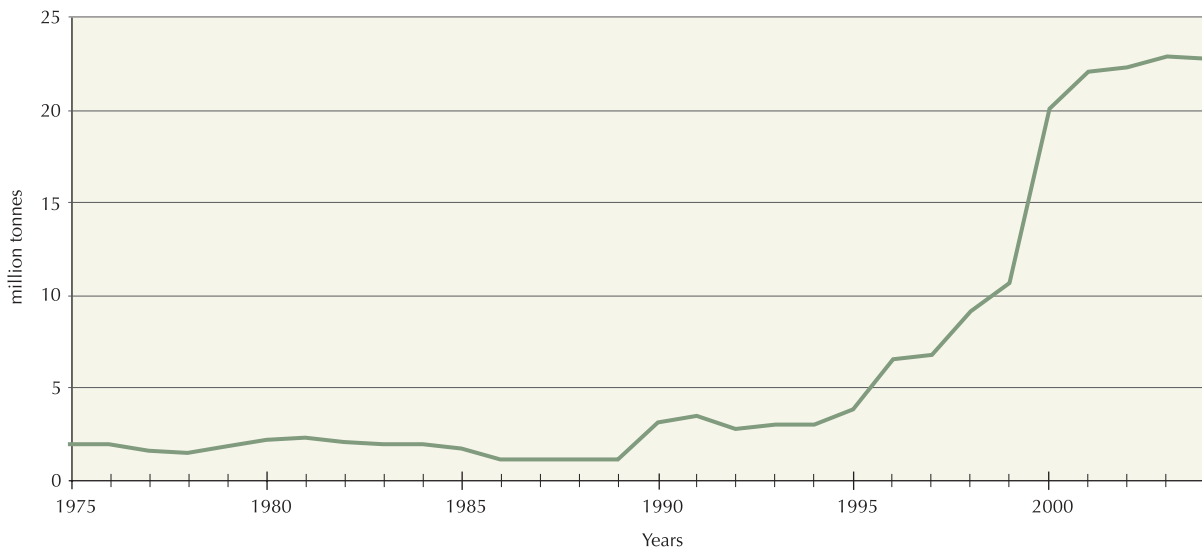
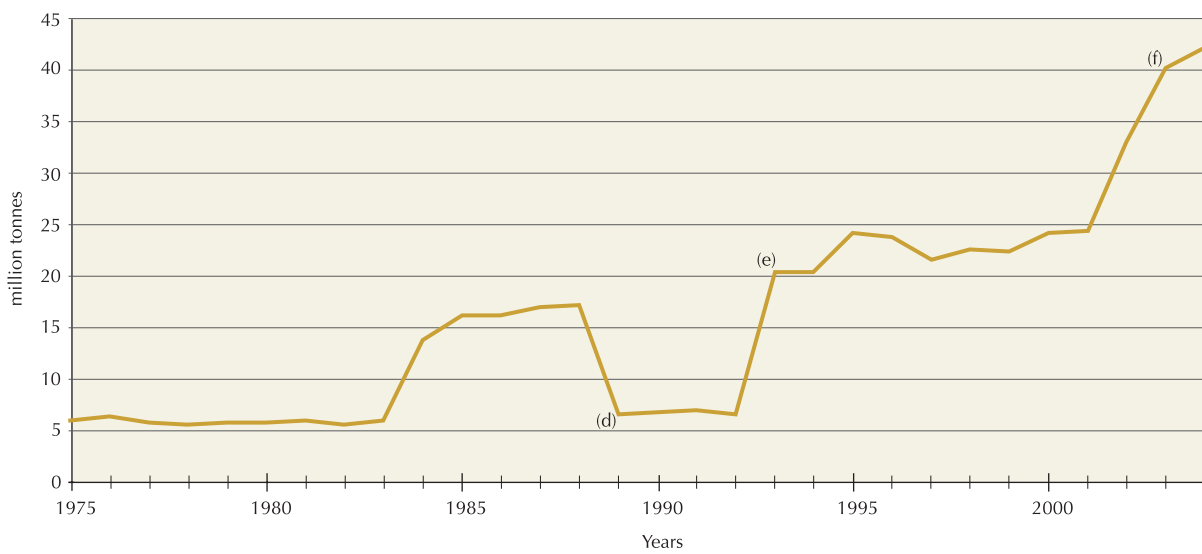


FIGURE 1: Trends in Economic Demonstrated Resources (EDR) for major commodities since 1975 (continued).

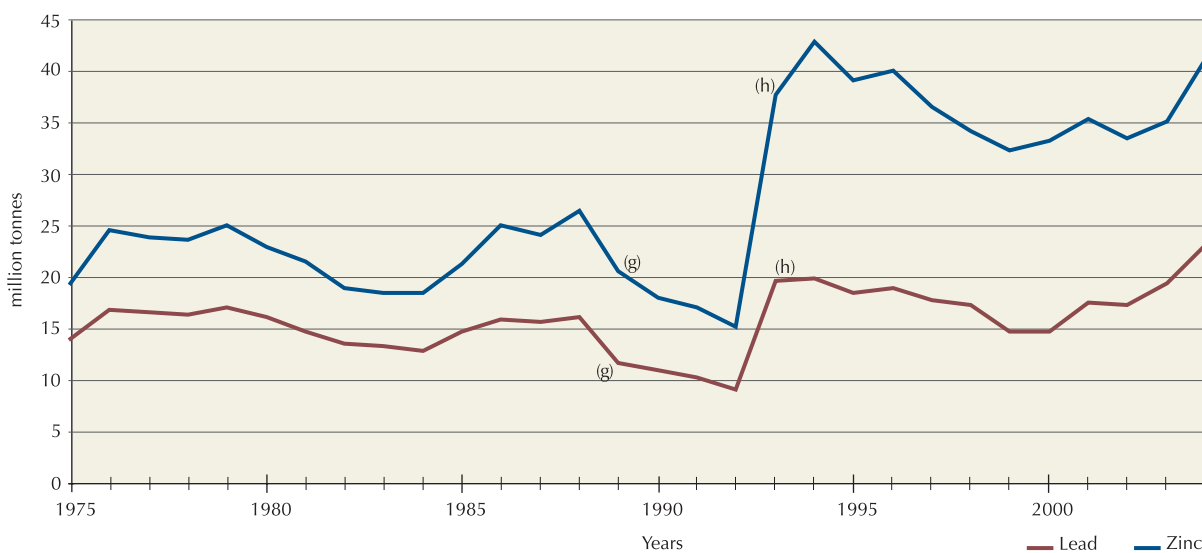
Nickel



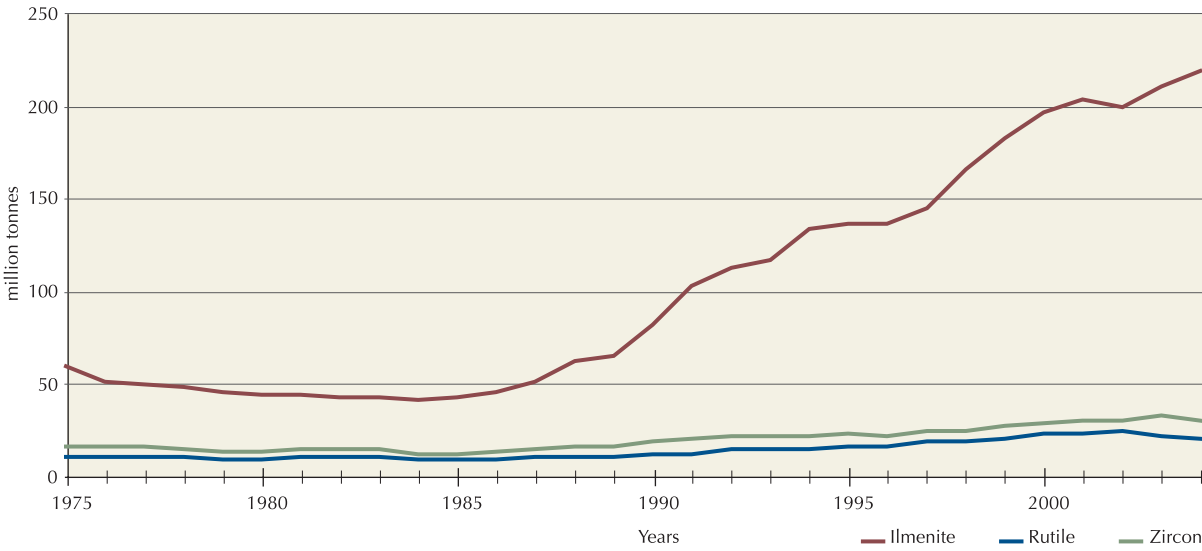
Copper



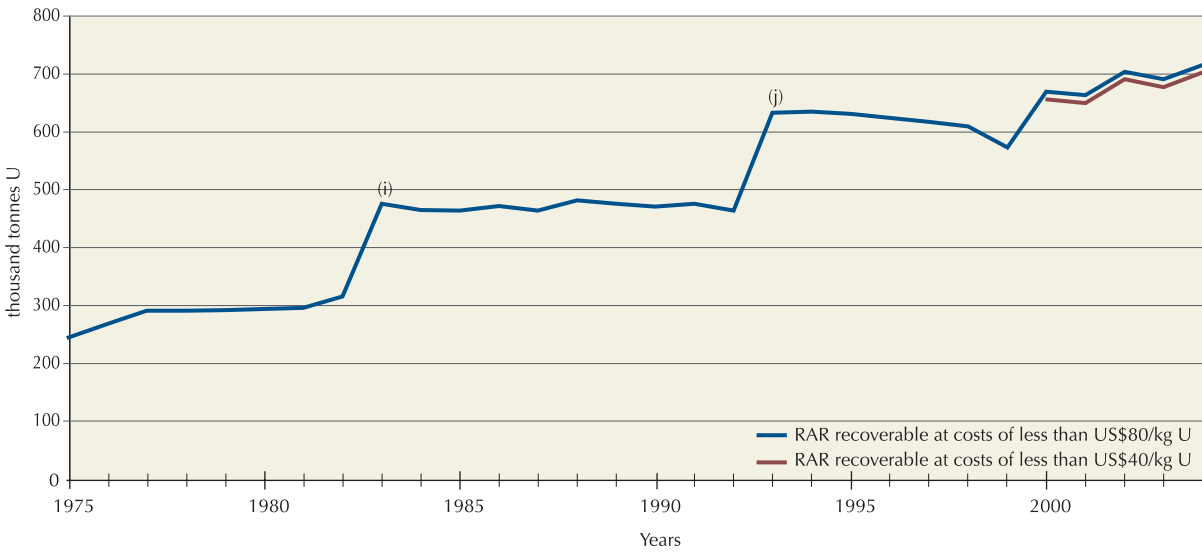
Lead, Zinc



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 Resources into EDR for McArthur River (NT) and Hilton deposits (Qld). Additional resources were also reported for Century and Cannington deposits (Qld) ('h').

Mineral Sands

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

Uranium

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

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

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

COMMODITY REVIEWS



Headframe at the Osborne underground mine, Queensland (Placer Dome Inc).

Bauxite

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

Over 85% of the bauxite mined globally is converted to alumina for the production of aluminium metal, an additional 10% goes to nonmetal uses in various forms of specialty alumina, and the remainder is for nonmetallurgical 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 (NaAlF_6).

Australia's aluminium industry is a large integrated sector of mining, refining, smelting and semi-fabrication, which is of major economic importance nationally and globally. The total value of all sector exports was over \$7.8 billion in 2004. The industry consists of five bauxite mines, seven alumina refineries, six primary aluminium smelters, twelve extrusion mills and two rolled product (sheet, plate and foil) mills. It directly employs over 16 000 people (indirectly many more) and is particularly important in regions such as North Queensland, the Hunter Valley, Southwest Victoria, Southwest Western Australia, the Northern Territory and North Tasmania.

Resources

Vast resources of bauxite, located in the Weipa and Gove regions adjacent to the Gulf of Carpentaria and in the Darling Ranges south of Perth, underpin the long-term future of Australia's 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 2004 represented an increase of over 3% compared to the previous year. As with the previous year, the increase resulted from a net effect of new drilling, changes in cut-off grades, mining depletion and reclassification of resources. Subeconomic demonstrated resources decreased by just under 0.1 Gt following upgrading of some resources to EDR in Queensland. Expansion of the Weipa bauxite mine resulted in a significant increase in production from the mining and processing of lower grade ores. Inferred resources increased by over 80% to 1.1 Gt due to reclassification of resources by companies when aligning with JORC standards, principally in Western Australia.

Accessible EDR

Less than 10% of bauxite EDR is inaccessible for mining. This involves small areas of the Darling range (WA) within mining leases, where for environmental reasons bauxite is not available for extraction. The ratio of AEDR to current mine production shows the resource life for existing bauxite operations is on average around 70 to 80 years. The potential of unexplored regions, however, is likely to extend resource life well beyond this.

JORC Reserves

Approximately 35% of AEDR comprises JORC Code reserves. The remaining represents resources assessed by Geoscience Australia as being economically recoverable from industry's *measured* and *indicated* categories of *mineral resources*, as defined under the Code and other classification systems used by non-listed ASX companies.

Exploration

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

Production

Globally in 2004, Australia was the leading producer of bauxite and alumina, and aluminium metal production was the highest recorded level. In 2004, production totalled 56.6 Mt of bauxite, 16.5 Mt of alumina and 1.9 Mt of aluminium (ingot metal). In comparison to 2003 this represents an increase of 1.8% for bauxite with no change for alumina and aluminium.

World Resources

Based on USGS data for other countries, Australia's demonstrated bauxite resources of 7.7 Gt rank second in the world after of Guinea and ahead of Brazil, Jamaica and China.

Industry Developments

Strong markets for aluminium in North America, with growth in demand of around 10% together with increased demand from China, resulted in the primary aluminium market moving into deficit for the first time since 2000. In 2004, the annual average price of aluminium increased to 78 US cents per pound, an increase of 20% against the average in 2003.

Expansion of the Weipa bauxite mining operation in Queensland was completed, resulting in an increase in production capacity to 16.5 Mtpa. This supports the new Comalco Alumina Refinery at Gladstone, the first stage of which was completed in late 2004. The mining upgrade relates to a move to simultaneous mining at Weipa's Andoom and East Weipa mines and involves a change in ore characteristics (fine ore) to that previously being mined. Integral to this expansion is a 9.5 Mtpa beneficiation plant to allow the mining of lower grade fine ores. The next infrastructure activity will be construction of a new US\$42 million power station to service the Weipa mining operations and surrounding communities.

Alcan has significant reserves of bauxite within its Ely/Ducie-Wenlock lease located approximately 25 km north of Weipa. Under an agreement with Comalco, the Ely deposit will be integrated into Comalco's overall mining plans, with mining forecast to start about 2010. A drilling program to further evaluate the Ducie-Wenlock deposit, which is contained within the same mining lease as Ely, commenced in 2004.

The Queensland Government's Aurukun bauxite project moved ahead during 2004 following investigations by Brisbane-based IMC Consultants, who found there were sufficient resources of bauxite at the Aurukun site (some 90 km south of Weipa) to warrant further exploration to fully delineate the deposit and investigate establishment of a mine and alumina refinery. The Government committed to a three-stage competitive bid process comprising Registration of Interest, Expression of Interest, and Binding Bids. The objectives for development of the Aurukun resource include its development as a source of bauxite for a new alumina refinery in Queensland.

In late 2004, Alcan announced it would proceed with a US\$1.3 billion expansion of its Gove alumina refinery in the Northern Territory. Lifting the refinery's capacity from 2.1 to around 3.8 Mtpa, the project will significantly improve operating efficiency and enhance environmental performance.

The strong international demand for mineral resources has resulted in renewed interest in bauxite deposits in northern Western Australia. The Minister for State Development granted the Mitchell Plateau Joint Venture a seven month extension to the end of April 2005 to submit detailed proposals to develop the Mitchell Plateau bauxite resource in the Kimberley region. The extension also provides further time for the Government to test third-party interest in developing a mining and refining project in the region based on the resource.

In Western Australia, Alcoa's Pinjarra refinery is aiming to improve its greenhouse intensity by around 12% through a \$440 million refinery upgrade and the construction of two cogeneration power units, which will produce power for the State's electricity market and provide waste heat for the Pinjarra refinery. The units will be owned by Alinta Limited and operated by Alcoa, who will take all steam produced by the facility for use in its refinery. Cogeneration is more than 80% energy efficient, compared with 25–50% for other power plants operating in Western Australia.

At Western Australia's other integrated bauxite mining and alumina refining operation, the Worsley joint venture committed to a series of development capital projects designed to take advantage of latent capacity in plant through a series of 28 packages of work estimated to cost US\$192 million. The result will be an increase in alumina production of 250 000 tonnes per annum to a capacity of 3.5 Mtpa. Commissioning and completion of the projects is expected in by the first quarter of 2006 with the resulting production ramp-up to be achieved by around mid-year.

Black Coal

Coal is a sedimentary rock of organic origin composed mainly of carbon. The higher rank black coals are mainly used in the generation of electricity and the production of coke in the iron and steel industry. Other uses include manufacture of cement and food processing and organic chemicals prepared from by-products of coke making. Australia has a substantial black coal industry dominated by New South Wales and Queensland. Locally significant operations occur at Collie (WA), Leigh Creek (SA) and the Fingal Valley (Tas).

Resources

In-situ and recoverable EDR each increased by 5% in 2004 to 57.4 Gt and 40.4 Gt respectively. This was due mainly to price increases and new mining methods that resulted in uneconomic coal being reclassified as economic as at Togara North and Togara South. New economic deposits in Queensland include Broughton, Isaac Plains and West Rolleston. Queensland (57.7%) and New South Wales (38.5%) had the largest share of recoverable EDR.

In-situ paramarginal demonstrated resources (PDR) decreased by over 35% to 8.1 Gt and recoverable PDR decreased by over 40% to 2.7 Gt due largely to the reclassification of a number of resources, including Togara North and Togara South. In-situ and recoverable subeconomic demonstrated resources (SDR) remained relatively unchanged at 12.6 Gt and 8.7 Gt respectively. Decreases in SDR at the Mandalong, Munmorah and Myuna deposits were offset by increases in SDR at the Mannering and Cordeaux deposits. In-situ and recoverable inferred resources remained almost unchanged at 85.5 Gt and 52.7 Gt respectively. The newly reported Anvil Hill and Athena inferred resources were offset by decreases of inferred resources at other deposits such as Warkworth and Kestrel.

Accessible EDR

Nearly all black coal EDR is accessible with only a relatively small tonnage at Hill River (WA) quarantined within State Reserves. The resource life of Accessible EDR (40.3 Gt) is greater than 100 years at current rates of production.

JORC Reserves

JORC reserves are 13.1 Gt or 32% of Accessible EDR. Included in this figure is Geoscience Australia's estimate for 19 operating mines, which do not report JORC reserves. This constitutes 2.5 Gt or about 6% of Accessible EDR. BHP Billiton, Rio Tinto, Xstrata Coal and Anglo Coal manage close to 70% of JORC reserves in Australia. The resource life of JORC reserves is 35 years at current production.

Exploration

Data published by ABS show that exploration expenditure for coal in 2004 totalled \$96.9 million, an increase from \$84.7 million in 2003. Expenditure in Queensland was \$75.1 million (77.5% of total), and \$16.7 million in New South Wales (17.2% of total). Exploration also occurred in South Australia, Western Australia and Victoria.

Production

In 2004, Australia produced 375.2 Mt of raw coal (358.4 Mt in 2003), which yielded 298.0 Mt of saleable coal (280.7 Mt in 2003). Black coal exports during the period amounted to 116.8 Mt of coking coal (valued at \$7.8 billion) and 106.9 Mt of steaming coal (valued at \$5.5 billion). ABARE has projected that Australia's saleable production will grow to 364 Mt by 2009–10.

World Ranking

Australia has 5% of the world's recoverable black coal EDR and ranks sixth behind USA (28%), Russia (20%), China (13%), India (12%) and South Africa (7%). It produced about 7% of the world's saleable black coal in 2004 and ranked fourth after China (37%), USA (22%) and India (8%).

INDUSTRY DEVELOPMENTS – QUEENSLAND

Pacific Coal: At Hail Creek a \$300 million expansion from 5.5 to 8 Mtpa is scheduled to be completed by mid-2006 with the introduction of a second dragline. Underground longwall mining commenced in the Ti Tree zone at the Kestrel mine. The \$400 million Clermont open-cut thermal coal project is being investigated as a replacement for the 12 Mtpa Blair Athol mine when operations cease in about 2009. A decision on whether to proceed is expected in 2005.

BHP Billiton Mitsubishi Alliance (BMA): At Blackwater, construction commenced in early 2004 on a US\$180 million 14 Mtpa coal handling and preparation plant. The plant will process the entire production from Blackwater and replace existing high cost plants. Commissioning is scheduled for late 2005. In April 2004, development driveage commenced at the Broadmeadow punch longwall project following completion of highwall preparation. The 3.5 Mtpa mine is expected to commence in mid-2005.

In March 2004, BMA announced plans to increase coking coal production from 52 to 57 Mtpa by mid-2005 at a cost of US\$94 million. The plan includes purchasing additional equipment for Saraji, Peak Downs and Goonyella mines, upgrades to processing plants at Saraji and Peak Downs and awarding of overburden stripping contracts. The next stage is estimated to cost \$US75 million and increase production to 59 Mtpa by mid-2006 and includes acquisition of additional stripping and mining equipment and awarding an overburden stripping contract at Saraji.

Xstrata Coal: The \$290 million Rolleston open-cut thermal coal project commenced construction in early 2004 and initial production of 1 Mtpa is expected in 2005. Full production of 6 Mtpa of export and 2 Mtpa of domestic product is scheduled for 2008. The operation is expected to have a mine life in excess of 20 years and has further expansion potential to 12 Mtpa with minor additional capital. At Newlands, development continued on the Northern underground punch longwall mine with full production expected in late 2005 to replace production from the existing Southern underground mine, which is due to close in late 2005. Production commenced at the Suttor Creek and Eastern Creek open-cut thermal coal mines near the Newlands operation.

Anglo Coal: Construction at the \$250 million Grasstrees underground longwall mine commenced in 2001 and is due to be commissioned in 2006 at a capacity of 5 Mtpa. The mine is designed to replace production from the Southern Colliery at the German Creek project. Open-cut production commenced in early 2004 at the Oak Park open-cut mine near the German Creek project. The Lake Lindsay open-cut coking and thermal coal project is currently undergoing feasibility studies to possibly commence mining in 2006. Feasibility studies are continuing on the \$500 million 5 Mtpa Grosvenor underground longwall coking coal project adjacent to the Moranbah North mine. At Moura, Anglo announced a US\$600 million plan to increase production from 7 to 12.7 Mtpa by 2007. Anglo intends to establish two additional operations near the Moura mine with the new and expanded operations to be known as the Dawson Complex.

Macarthur Coal: At Coppabella the first coal was mined from the South Pit in early 2004. The new Moorvale mine was expanded from 1.6 to 2 Mtpa from early 2004. The Olive Downs, Moorvale West and Codrilla deposits are all being considered as satellite operations to the Moorvale mine. Development is dependent on the expansion of the Dalrymple Bay Coal Terminal. Macarthur is undertaking a feasibility study into the West Rolleston open-cut thermal coal project as production could be shipped through the expanding Port of Gladstone. Construction is proposed to commence in mid-2006 with first production in 2008. In late 2004, Macarthur announced a feasibility study into establishing a new generation coke making facility near the Stanwell Power Station in Central Queensland. The facility will produce 300 MW of electricity and could begin producing coke by the end of 2007.



Moorvale coal mine, Bowen Basin, Queensland (Macarthur Coal Ltd).

Peabody Energy: Mining operations commenced at the \$195 million 1 Mtpa Eaglefield open-cut coking coal project. Production will supplement that from the nearby North Goonyella underground mine.

Wesfarmers: Construction of the \$290 million Curragh North open-cut project commenced in September 2004 and the first coal is scheduled to be produced by mid-2005. Coal will be transported via a 20 km conveyor system to the current Curragh processing plant, which is to be upgraded. Production is planned to increase from 6.5 to 9 Mtpa in 2006 and mine life will extend about nine years to 2025.

Felix Resources: The Yarrabee North mine extension commenced in June 2004. Construction at the \$68 million Minerva open-cut mine commenced in August 2004. Production of high volatile PCI and thermal coal is expected to commence in mid-2005 at a rate of 2.5 Mtpa and continue over an 11 year mine life.

Excel Coal: Construction of the \$60 million Millennium open-cut coking coal project commenced in December 2004 and is expected to be completed in late 2005 with a capacity of up to 2.5 Mtpa.

Tarong Energy: The proposed Glen Wilga open-cut thermal coal project near Chinchilla is initially planned to produce 0.5 Mtpa. Planning is progressing on the development of a 150 km rail line from Brigalow to the Tarong Power Station.

Bowen Basin Coal Pty Ltd: The proposed Vermont open-cut mine, located about 15 km north-east of Dysart, is planned to produce 2.5 Mtpa of coking and PCI coal over 15 years.

Ensham Resources: Is investigating the development of a high capacity underground longwall operation at the Ensham mine, where production may be increased from 8 to 20 Mtpa by 2009.

Eastern Corporation: Are considering a proposal to commence open-cut production by 2007 at the Broughton coking and thermal coal deposit south of the Hail Creek mine.

American Metals and Coal International (AMCI): Plan to develop a trial underground coking coal mine at the Carborough Downs project near the Peak Downs mine. The mine will begin development with two continuous miners during 2005. AMCI and Aquila Resources plan to produce a feasibility study by mid-2005 for the Isaac Plains open-cut coal mine development, which is scheduled to commence production by July 2006.

INDUSTRY DEVELOPMENTS – NEW SOUTH WALES

BHP Billiton: The US\$200 million Dendrobium underground longwall mine is scheduled to commence operations in April 2005. It will be capable of producing up to 5.2 Mtpa of raw coking coal. To extend the mine life of the Appin project beyond 2006, the mine plan requires coal extraction under the Nepean River to Menangle and Douglas Park.

Coal and Allied: Mt Thorley and Warkworth mines have been managed as one operation since January 2004. The Mt Pleasant open-cut thermal coal deposit development options include integration with Bengalla or a smaller stand alone operation.

Xstrata Coal: At Ulan a new \$90 million 400 m wide longwall system with 2 m wide supports is to be installed creating the widest longwall face in Australia. The system will be capable of producing 5.5 Mtpa and is expected to be in operation in late 2005. This will ensure the future of the Ulan mine for at least another 20 years after closure of the Ulan open-cut mine in late 2007. At Mt Owen, Xstrata plan to extend the approved mining operations by approximately 500 m. At Cumnock a study is in progress to determine whether the remaining resource can be economically mined beyond 2008.

Anglo Coal: The new Kayuga underground longwall mine commenced operations in mid-2004 at the Dartbrook project. The Saddlers Creek deposit is proposed to be a combined open-cut and underground operation.

Centennial Coal: The \$185 million Mandalong project commenced longwall operations in January 2005 at a rate of up to 4.0 Mtpa. In October 2004, Centennial signed a long term contract with Macquarie Generation to supply 30 Mt of thermal coal from the Anvil Hill project over 12 years from 2008. The Mannering Colliery (previously Wyee) commenced a “super panel” continuous miner operation in January 2005 at a rate of 0.5 Mtpa using. The Clarence mine was expanded by 1.2 Mtpa in 2004 by introducing a third super place change unit. Mining commenced on a small open-cut (Lamberts Gully) at the Springvale project. Newstan Colliery has plans for a drift to be driven from the Awaba mine to reduce travel times and increase capacity by 0.5 Mtpa. Work commenced in December 2004 on the Fassifern Auger Mine. The new Southern open-cut commenced at Charbon during 2004. The Ivanhoe mine closed in March 2004 after 96 years of operation.

Austral Coal: The new \$130 million Tahmoor North longwall was commissioned in June 2004 at a planned rate of production of 4 Mtpa over 8 years. The Tahmoor longwall ceased operations in March 2004.

Excel Coal: In January 2005, Excel commenced expansion of the Wambo open-cut coal mine to 7.5 Mtpa by purchasing \$56 million of mobile equipment and spending \$44 million building a 15 km rail link to the Mt Thorley rail loader, which is scheduled for completion in late 2005. Excel also commenced an upgrade of the coal handling and preparation plant capacity to 10 Mtpa (raw) and plan to develop two new longwall operations. At the Metropolitan Colliery production is to be increased to 1.5 Mtpa by mid-2005 and at Chain Valley capacity was doubled to 0.7 Mtpa by installing a second continuous miner. The \$156 million Wilpinjong open-cut thermal coal project is planned to deliver up to 7 Mtpa to Macquarie Generation from 2007 for 19 years.

Gloucester Coal: At Duralie a feasibility study is underway to evaluate mining underground resources with trial mining planned for 2006/07. After exhaustion of the Bowens Road North mine, Bowens Road South, Roseville, Cloverdale and Avon North deposits are scheduled to be mined.

White Mining Ltd: The \$110 million 1.6 Mtpa Ashton open-cut mine commenced in early 2004. Underground development is due to start in 2007 at 2.1 Mtpa ahead of a 3.0 Mtpa longwall operation planned to start in 2009. At Moolarben, a 4.0 Mtpa open-cut thermal coal mine is scheduled to commence operation in 2008 with a 3.0 Mtpa underground mine to commence in 2010.

Resource Pacific Holdings: The Newpac No1 Colliery (previously called Nardell) commenced operations in April 2004 using continuous miners at a rate of 0.6 Mtpa. The company plans to introduce longwall mining producing 4.0 Mtpa by 2008. At Bellpac No1 (previously known as Bellambi West Colliery), a study is examining the viability of accessing coal in the western area through a sub-lease of infrastructure at the former Cordeaux mine and processing coal at the Dendrobium Colliery.

Yanzhou Coal Mining: Southland was sold for US\$23 million and Yanzhou plan to install a new \$100 million 2 Mtpa longwall operation by mid-2006. The new Austar mine development is planned to begin in during 2005.

AMCI: A development application has been submitted for a 1.6 Mtpa open-cut thermal coal mine at Werris Creek, which will have a mine life of seven years.

Northern Energy Corporation (previously known as Poltech International): A bankable feasibility study is to be undertaken on the historic Ashford coal deposit near Inverell in northern NSW.

Newcastle Coal Company: The Tasman underground thermal coal mine is proposed to be developed at a rate of 1.0 Mtpa using bord and pillar methods.

Whitehaven Coal Mining: The Belmont open-cut thermal coal mine is proposed to be developed with a capacity of 1.5 Mtpa. Whitehaven and Idemitsu Boggabri Coal are planning to commence an open-cut thermal coal mine at East Boggabri in late 2005.

Bloomfield Collieries: The Bickham open-cut thermal coal mine is planned to be developed with production of up to 2.5 Mtpa.

Muswellbrook Coal Company: Propose to develop the Sandy Creek underground thermal coal mine.

Hunter Enviro-Mining: Plan to restart operations at Hebburn No2 Colliery near Cessnock to clean up and revegetate the mine site. Some \$11 million is to be spent to rehabilitate the site, which closed in 1972. The project is expected to produce 300 000 t of coal over a four year operating life.

INDUSTRY DEVELOPMENTS – WESTERN AUSTRALIA AND SOUTH AUSTRALIA

In Western Australia, the **Aviva Corporation** propose to supply coal from the Central West Coal Project near Eneabba to a pig iron enterprise in the mid-west and/or to a 300 MW mine mouth power station supplying 1.8 Mtpa over 25 years from 2008. Wesfarmers are planning to increase production at Collie to about 5 Mtpa by 2007 and are also planning a \$5 million char-making demonstration plant. In South Australia **NRG Flinders** has taken a six year option from Felix Resources over the Phillipson Basin coal tenements.

INDUSTRY DEVELOPMENTS – INFRASTRUCTURE

In Queensland, a reclaiming boom at the Dalrymple Bay Coal Terminal collapsed in mid-February disrupting coal loading capacity until mid-April 2004. **Prime Infrastructure** is increasing the capacity at the Dalrymple Bay Coal Terminal from 55 to 60 Mtpa by early 2006 at a cost of \$30 million. In late 2004, Prime Infrastructure commenced a detailed engineering and design program for a \$600 million staged expansion to 90 Mtpa. At the Hay Point Coal Terminal, US\$100 million is to be spent to increase capacity from 32 to 40 Mtpa as part of BMA's coking coal expansion plans. The R.G.Tanna Coal Terminal at the Port of Gladstone is undergoing a \$167 million expansion from 40 to 54 Mtpa commencing in early 2005. The new infrastructure includes a third rail unloading station, a third shiploader, a fourth berth and two additional coal stockpiles.



Hay Point and Dalrymple Bay coal export terminals, Queensland (Prime Infrastructure Management Ltd).

In New South Wales at the Port of Newcastle, Port Waratah Coal Services (PWCS) has submitted preliminary plans to expand capacity from 89 to 120 Mtpa. The first stage to 100 Mtpa would be commissioned in late 2007. PWCS introduced a Capacity Distribution System in March 2004 to allocate coal supply chain capacity between coal producers to cap the tonnage producers could export. The system was authorised by the Australian Competition and Consumer Commission to reduce the queue of vessels waiting off Newcastle. A new group, Newcastle Terminal Developments, is proposing a three stage \$400 million terminal development with an ultimate capacity of 45 Mtpa. The initial 15 Mtpa development would cost \$200 million.

Queensland Rail is constructing a \$230 million 110 km rail spur from Blackwater to the new Rolleston coal mine in Central Queensland. The Queensland Government is planning an expansion of the coal rail system to 202 Mtpa by 2010. In New South Wales, the Australian Rail Track Corporation is planning to invest \$152 million over the next five years to upgrade the 450 km of track and signalling in the Hunter Valley network to lift capacity from 85 to 102 Mtpa by 2008. In August 2004 a number of coal producers in the Hunter Valley established the Newcastle Coal Infrastructure Group with the aim of ensuring that there is adequate long term capacity in the Hunter Valley export coal supply chain.

The New South Wales Government awarded White Mining Ltd (now owned by Felix Resources) an Exploration Licence over the Moorlaben coal tender area located 30 km northeast of Mudgee. The deposit contains about 300 Mt of in situ thermal coal of which 26 Mt is available for open-cut mining. During 2004 the Government changed the coal royalty rate from a fixed royalty of \$1.70/t or \$2.20/t for open-cuts to an ad valorem rate of 6% or 7% for open-cuts.

INDUSTRY DEVELOPMENTS – RESEARCH AND DEVELOPMENT

In March 2004, the COAL21 National Action Plan was announced. It aims to reduce or eliminate greenhouse gas emissions from the use of coal in Australia's electric power generation industry. The Plan identifies a number of suitable technologies including coal gasification and carbon dioxide capture and underground storage (geosequestration). Australian Black Coal producers pay 5 cents per saleable tonne to fund the Australian Coal Association Research Program (ACARP), which aims to research, develop and demonstrate technologies that lead to safe, sustainable production and utilisation of coal. The Centre for Low Emission Technology has the primary focus on research and development of new generation low emission electricity generation technologies. An additional focus will be to develop technologies to improve the performance of existing coal fired power stations such as oxy-firing and coal-renewable hybrid technologies. The Western Australian Government is investigating establishing a Clean Coal Centre of Excellence at Collie to conduct research into clean coal technologies.

Brown Coal

Brown coal or lignite has a much lower carbon and higher moisture content than black coal. Its main use is in the generation of electricity. Other uses include the production of water gas, industrial carbon and briquettes for heating. In Australia, deposits of brown coal are Tertiary in age (15–50 million years) and occur in all states. There are substantial resources in Victoria (the only state that mines brown coal), and in particular the La Trobe Valley, where four mines in major shallow deposits provide fuel to mine mouth power stations that generate much of the state's electricity. At Morwell brown coal is used to make briquettes for industrial and domestic heating.

Resources

Recoverable EDR for 2004 was 37.5 Gt, unchanged from 2003. Recoverable PDR, SDR and inferred resources were also the same at 39.0 Gt, 16.3 Gt and 100.8 Gt respectively. Victoria accounts for over 96% of Australia's identified resources of brown coal. All EDR is in Victoria and just under 90% of the total EDR is in the La Trobe Valley.

Accessible EDR

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

JORC Reserves

Reported brown coal resources estimates do not comply with the JORC Code. Geoscience Australia's assessment of brown coal at the operating mines is based on published information. Reserves are assessed at about 2.1 Gt with 70% being at Loy Yang. The resource life of published reserves is over 30 years.

Exploration

Data relating to exploration for brown coal specifically are not available nationally. However, the Victorian Department of Primary Industries reported in 2003–04 that \$1.2 million was spent on brown coal exploration and \$145 million on brown coal mining development.

Production

Australian brown coal production in 2003–04 totalled 66.3 Mt (valued at \$531 million) all of which was from Victoria. The La Trobe Valley mines of Yallourn (16.6 Mt), Hazelwood (19.1 Mt) and Loy Yang (29.6 Mt) produce about 98% of Australia's brown coal. Locally significant brown coal operations occur at Anglesea (1.1 Mt) and Maddingley (18 kt).

World Ranking

Australia has about 24% of the world's recoverable brown coal EDR and is ranked number one in this category. Germany's recoverable EDR have declined significantly from 43 Gt to 6.6 Gt in recent years – Australia produces about 8% of the world's brown coal and is the fifth largest producer after Germany (22%), Russia (10%), USA (9%) and Greece (8%).

Industry Developments

CLP Power Asia, owner of the **Yallourn** mine and power station, is undertaking a \$1 million feasibility study into building a coal gasification facility to provide fuel for a 500 MW power station. Construction of the plant could begin in 2006 if the feasibility study produced favourable results.

In April 2004, the **Loy Yang** mine and power station was sold to the Great Energy Alliance Corporation, which is a joint venture of the Australian Gas Light Company, Tokyo Electric Power Company and a group of investors led by the Commonwealth Bank of Australia. In October 2004, the Loy Yang mine reached a milestone with extraction of the 500 millionth cubic metre of material. The mine now extends 3.2 km by 2.1 km and at the deepest point is 180 m below ground level.

In May 2004, International Power submitted an Environmental Effects Statement for the \$380 million West Field development at the **Hazelwood** mine. International Power plan to extend the mines operation from 2009 to 2030 by relocating a section of the Strezlecki Highway, diverting the Morwell River and two creeks, and moving the town of Driffield and eleven families.

Anglo American outlayed \$52 million purchasing the remaining 80% of Australian Power and Energy Ltd (APEL) it did not already own. APEL has exploration tenements over the 3 Gt Flynn coal deposit near Traralgon. Scoping studies indicate that 62 000 bpd of diesel can be produced in a two stage processing plant costing up to \$5.5 billion. The 220 MW's of electricity generated by the plant would be needed in the manufacturing process.

The Cooperative Research Centre (CRC) for **Clean Power from Lignite** successfully trailed a process for drying brown coal, which can reduce greenhouse gas emissions from power stations by a third or more. The CRC's Mechanical Thermal Expression (MTE) technology removes more than 70% of water from brown coal. The next stage is to build a \$6.3 million pilot plant in the La Trobe Valley with construction planned for late 2005 and testing to start in early 2006. The pilot plant would process up to 15 t of brown coal per hour.

The Victorian Department of Primary Industries is undertaking a study into the development of the La Trobe Valley brown coal resources over the period to year 2100. The study, '*La Trobe Valley Coal Resources 2100*', will consider the interplay between the future mining infrastructure, the community and the environment over the next 100 years.

Copper

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

Resources

Australia's EDR rose by 2 Mt to slightly more than 42 Mt of copper, an increase of 5%. South Australia has the largest EDR, which increased by 4% in 2004 and is now around 60% of the national total. The majority of these resources are associated with the Olympic Dam deposit where EDR increased by just over 1.5 Mt following development drilling at the main deposit and the use of a 29% higher long-term price for uranium in resource calculations. Queensland has the second largest EDR with 21% of the national total, followed by Western Australia (8%) and New South Wales (6%). An increase in EDR for Queensland of 16% (1.2 Mt) relates mostly to the results of the Mt Isa Open Pit pre-feasibility study undertaken over the last two years.

Subeconomic demonstrated resources increased by 13% to 4.9 Mt, made up of 3.6 Mt in the paramarginal demonstrated resource category and 1.3 Mt in the submarginal demonstrated resource category. The increase of 0.6 Mt in paramarginal resources compared to 2003 reflects activity in the Mt Isa region of Queensland where evaluation of a range of deposits is in progress. Most of the paramarginal resources are in Western Australia and Queensland with 29% and 28% respectively, followed by New South Wales (21%).

Inferred resources rose by 8 Mt (35%) to just under 30 Mt in 2004. The increase was predominantly in South Australia where inferred resources rose by over 70% (8 Mt) to over 19 Mt, primarily as a result of extensive exploration drilling at Olympic Dam to the south east of the main deposit, and at Prominent Hill where 1.455 Mt of inferred resource was announced during 2004. South Australia holds 65% of Australia's inferred resources followed by Queensland and Western Australia both with 11%.

Accessible EDR

All copper EDR is accessible.

JORC Reserves

JORC Code reserves account for around 47% 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 62% in 2004 to \$55.8 million. Expenditure in South Australia (\$24.6 million) was over 40% of all copper exploration and was directed mainly on the search for Olympic Dam style mineralisation in the Gawler Craton. This state's expenditure also includes resource definition drilling at Prominent Hill, where an inferred resource of 97 Mt @1.5% Cu and 0.5 g/t Au (cut-off grade of 0.5% Cu) has been identified. Queensland had 34% of spending on exploration for copper and New South Wales 12%, with the remaining 10% distributed largely in Western Australia and to a lesser extent in the Northern Territory, Tasmania and Victoria. Significant exploration results reported during 2004 include:

Kalkaroo (SA): In the Curnamona Craton, 100 km west of Broken Hill, Havilah Resources NL reported an intersection of 36 m @ 3.1% Cu and 1.0 g/t Au. Mineable grades of molybdenum were also noted. Mineralisation has been traced over 1 400 m around a large arc. The company drilled fourteen 100 m spaced drill traverses with resulting ore-grade intersections along each.

Einaleigh (Qld): Copper Strike Ltd announced copper intersections from drilling at its Einaleigh Copper Mine prospect 300 km northwest of Townsville. Intersections reported include 50 m @ 6.65% from 235 m, 15 m @ 11.76% Cu from 244 m and 11 m @ 3.10% Cu from 269 m downhole.

Roseby (Qld): Universal Resources Ltd reported resource estimates (all categories) totalling 103 Mt @ 0.69% Cu and 0.06 g/t Au for several deposits comprising the Roseby project near Mt Isa.

Lady Annie (Qld): 137 km north of Mt Isa, drilling by CopperCo Ltd yielded an intersection of 22 m @ 6.7% Cu from 173 m downhole in transitional chalcocite ore below the Lady Annie oxide resource. The company had previously released a resource estimate (all categories) of 10.5 Mt @ 1.0% Cu for oxide resources at Lady Annie.

West Whundo (WA): Near the Radio Hill mine in the Pilbara District, Fox Resources Ltd reported a drill intersection of 10 m @ 23% Cu, 0.41% Co and 2.6% Zn. West Whundo is part of the Whundo project, which is based on the old Whundo copper mine.

Balcooma (Qld): Kagara Zinc Ltd undertook a limited drilling program on the Balcooma North prospect near Greenvale to test for extensions of the deposit and to obtain metallurgical samples. One hole intersected 12.2 m @ 15.7% Cu and a second hole gave 15.6 m @ 6.1% Cu.

Cloncurry (Qld): Exco Resources NL released an initial resource estimate for the Great Australia deposit at its Cloncurry copper project. Indicated and inferred resources to a depth of 150 m total 2.13 Mt @ 1.54% Cu and 0.13 g/t Au. At the Monakoff deposit, also part of the Cloncurry project, the company reported an indicated and inferred resource of 1.9 Mt @ 1.58% Cu and 0.48 g/t Au.

E1 East (Qld): 8 km east of the Ernest Henry mine northeast of Cloncurry, Exco Resources NL reported drill intersections including 72 m @ 1.25% Cu and 0.4 g/t Au, 42 m @ 1.75% Cu and 0.59 g/t Au and 108 m @ 0.68% Cu and 0.2 g/t Au.

Kanmantoo (SA): At the old Kanmantoo copper mine, Hillgrove Resources Ltd, announced an inferred resource based on evaluation of old drill holes of 8.4 Mt @ 1.2% Cu. Some 500 m south of Kanmantoo, the company previously reported drilling had defined two broad zones of copper mineralisation which included an intersection of 27 m @ 3.94% Cu.

Production

In 2004, Australia's mine production of copper was 860 kt of contained copper, 4% higher than in 2003 (829 kt). Queensland continued to dominate production with 399 kt (largely from Mt Isa), which is 8% less than in 2003, and accounts for 48% of Australian production, down from 53% in 2003. South Australia remained the second largest producer with 225 kt (up 40% and all from Olympic Dam), representing 27% of Australia's production. Other production was: New South Wales (166 kt, up 8%), Western Australia (38 kt, down 22%), and Tasmania (32 kt, up 7%).

The value of Australia's exports of copper concentrates and refined copper totalled \$2.57 billion, 27% more than in 2003 (\$2.02 billion) and 1.7% of the value of total merchandise exports. The increase reflects higher copper prices in 2004 with the average up by 43% to \$3 915/t compared to the average of \$2 735/t in 2003. Although copper production was 4% higher in 2004, the tonnage of exports was 7% lower at 654 kt. ABARE forecast that mine output of copper will reach 1.08 Mt in 2008–09.

World Ranking

Based on USGS data for other countries, Australia has the second largest EDR of copper (9%) after Chile (36%) and ahead of 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%), USA (8%) and Peru (7%), with Indonesia also at 6%.

Industry Developments

Mt Isa (Qld): Xstrata Plc plans to expand its Mt Isa copper smelter capacity from 240 000 tpa to 280 000 tpa by mid 2006 through the installation of a second rotary holding furnace, a copper slag cleaning furnace and a converter slag treatment plant. At Mt Isa's Enterprise copper mine a \$36 million development of the Northern 3 500 underground copper orebody has commenced. The project will provide an additional high-grade mining zone in Enterprise, enabling the mine to maintain its rated capacity of 3.5 Mtpa. Current plans indicate that the mining block will contribute a supplementary 5.3 Mt of copper ore at a grade of 4.5% (240 000 t of contained copper metal) over the next 11 years, with initial production scheduled to commence in late 2006.

Olympic Dam (SA): In May 2004, WMC Resources Ltd. began a \$48 million pre-feasibility study into options to further expand production and develop a preferred life-of-mine plan. As part of the study, over 70 km of drilling in 90 holes from surface identified significant additional mineralisation in the south-eastern region of the deposit. As a consequence, the Olympic Dam mineral resource (all categories) was upgraded in late 2004 to 3.81 billion tonnes @ 1.1% Cu, 0.4 kg/t U₃O₈ and 0.5 g/t Au – an increase of over 29%. Total copper in the resource increased by 7 Mt to an estimated 42.7 Mt. Options being investigated from the increase in resources include increasing annual copper production at Olympic Dam to 500 000 tonnes.

Prominent Hill (SA): Oxiana Ltd acquired full control in 2004 of the Prominent Hill copper-gold project.

Golden Grove (WA): Oxiana Ltd acquired the Golden Grove base and precious metals mine from Newmont Mining Corporation. Reserves at Golden Grove total 4.77 Mt at 6.9% Zn, 2.1% Cu, 0.9% Pb, 75 g/t Ag, and 1.3 g/t Au with an additional 12 Mt of resources for which drilling is being carried out to convert 70% of these to reserve status.

Eloise (Qld): Barminto, a mining contractor company, purchased the Eloise copper mine from Breakaway Resources Ltd.

Sulphur Springs (WA): CBH Resources Ltd acquired the Sulphur Springs copper-zinc deposit from Sipa Resources Ltd and announced it could bring the project online within 18 months. Sulphur Springs has a reserve of 4.4 Mt at 1.8% Cu and 5.6% Zn.

Telfer (WA): Newcrest Mining Ltd's re-development of Telfer as a gold-copper mine commenced with staged production in early 2005. It is expected to produce 800 000oz of gold and 55 000t of copper in 2006 with an expected mine life of 25 years.



Underground blast-hole drilling, Golden Grove mine, Western Australia (Newmont Australia Ltd)

Tritton (NSW): The Tritton copper mine, near Girilambone, commenced operations in 2004 (based on a total resource of 15.2 Mt at 2.7% Cu). It is expected to produce around 24 000 tpa of copper in concentrate over a 11-year life. Tritton will mainly be an underground operation with some ore extracted from a small open pit.

Diamond

Diamond is composed of carbon and is the hardest known natural substance, but a sharp blow can shatter it. It also has the highest thermal conductivity of any known material at room temperature. Diamonds are thought to form 150–200 km below the Earth's surface at high temperatures (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 may accumulate in alluvial deposits. Diamonds may be found far from their source as their hardness allows them to survive multiple episodes of erosion and deposition.

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

Resources

EDR for gem/near gem was 53.4 Mc and industrial 55.6 Mc, both down 26% compared with 2003 due to Argyle mine production and introduction of a new resource model and revised mine plan, which resulted in some ore reserve being classified as mineral resource.

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 2004 was \$25.4 million, down 8% on 2003. Exploration continues to be concentrated in Western Australia, notably the Kimberley region, Northern Territory and South Australia.

Abner Range (NT): Gravity Diamonds Ltd announced the discovery of a diamondiferous kimberlite (ABN21) south of the McArthur River mine after drilling a Falcon® airborne gravity anomaly. Detailed ground gravity surveys and geological mapping are being conducted to outline the potential shape and size of the kimberlite body to enable more detailed test drilling and bulk sampling. A further 28 targets within 10 km radius of the ABN21 are to be mapped and sampled.

Seppelt (WA): Striker Resources NL continued exploration in the North Kimberley region at its Seppelt project, which comprises a number of related kimberlite dykes, blows and pipes over a strike length of some 6 km. At the Seppelt 2 pipe the largest diamonds recovered to date include one 8.5 c and one 6.3 c diamond. The 8.5 c clear white diamond is of gem quality and valued at US\$1 500 per carat. The 2004 work program focused on assessing the viability of open-pit mining at the high grade Seppelt 2 pipe (at 211 cpht for the weathered kimberlite), the Seppelt 1 pipe and the Seppelt 5 fissure as well as assessing the potential for underground mining at Seppelt 5 and Seppelt 2. Following the sale of 5 618 carats at an average price of US\$35/carat, largely from lower grade infill gravels, trial mining at Seppelt 2 was discontinued in favour of further exploration in the region and an immediate focus on advancing the Merlin Project.

Ellendale (WA): Kimberley Diamond Company Ltd discovered nine small pipes in 2004 (Kimberley Pipes 33 to 41), all within trucking distance of existing infrastructure at Pipe 9.

Flinders Ranges (SA): Flinders Diamonds Ltd reported the discovery 11 kimberlites, mostly in the Euralia region, three of which carry micro diamonds. Two small kimberlite pipes were also discovered in the Angaston region in the Adelaide Hills following detailed airborne and ground magnetic surveys and sampling.

Production

Australia produced 20.7 Mc of diamond in 2004, making it the world's fourth largest producer of diamond by weight after Botswana, Russia and Congo (Kinshasa). As a producer of gem/near gem diamond, Australia is the fourth largest after Botswana, Russia and Canada and as producer of industrial grade diamond Australia is the third largest.

Production was almost entirely from the Argyle mine (AK1 pipe), which produced 20.62 Mc, mostly industrial and cheap diamonds with an average price of US\$15–16. Production was down substantially from the 30.91 Mc mined in 2003 as a consequence of difficult near-base-of-pit mining conditions, which resulted in mining of lower grade ore. The average grade mined for the year was 2.15 cpt (cf 3.16 cpt in 2003).

Production from Kimberley Diamond's Ellendale mine in the West Kimberley region increased to 82 039 c up from 57 000 c in the previous year. Production was from the Ellendale 9 pipe where high-value fancy yellow gem diamonds (average sale price in 2004 US\$258 per carat) were mined.

World Ranking

Australia's EDR of industrial diamond ranks fourth (10% of current world total EDR), after the Congo (Kinshasa), Botswana and South Africa (26%, 23% and 12% 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 Ltd continued development of a 2.2 km exploratory decline to 300 m depth to test the fragmentation and 'caveability' of the ore body below the open pit. This is part of a full feasibility study (costing \$70 million) to assess the viability of underground mining after the open-pit reserves are exhausted in 2008. A decision on the underground mine development option is expected in 2005.

Ellendale (WA): Expansion of Ellendale 4 operations is to proceed with a 4.4 Mtpa production plant to be fully commissioned by April 2006. This will increase production in the long-term to 7.2 Mtpa from 2.8 Mtpa currently.

Merlin (NT): Striker Resources NL acquired the Merlin mine and surrounding exploration tenements of 1 800 km² from Rio Tinto. A study found that some 19% of Merlin diamonds do not fluoresce and therefore were unlikely to have been recovered in previous mining. Striker has begun processing the entire sorthouse tailings stockpile comprising up to 10 000 t and estimated to have a grade of 950 cpht from a 1.8 t sample. An initial development will re-commence mining operations to process the remaining open pit ore, estimated at 475 000 t for which previously reconciled production grades may have understated the true kimberlite grades by more than 25%. Later stages include the cut-back of the Sacamore/Palomides pipe structures and possible underground mining. Striker estimate total resources in the Merlin Field to be 19 Mt at an average grade of 17.4 cpht for a total of 3.3 Mc.



Australia's largest diamond weighing 104.73 carats recovered from the Gareth pipe, Merlin (NT) and valued at US\$525 000 in 2002 (Striker Resources NL).

Gold

Gold prices maintained the higher levels through 2004 resulting in the year-end price of US\$438/oz and an average of around US\$410/oz. The continuing stronger price contributed to a substantial increase in spending on exploration for gold both in Australia and worldwide. There was a strong increase in the level of both EDR and total resources, however production was lower than in previous years. In 2004 gold contributed over \$5.5 billion to the Australian economy in export earnings.

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 2004, total Australian gold resources were 997 t higher than at the end of 2003. After allowing for the replacement of those resources lost to production (259 t), newly delineated resources added to the national inventory totalled 1 256 t (40 Mozs) in 2004. Inventories grew in Queensland, Victoria, New South Wales and South Australia.

Australia's EDR rose by 207 t (6.7 Mozs) in 2004 to 5 589 t and accounted for 82% of total demonstrated resources, a small increase on the share in 2004. In 2004, EDR increased in New South Wales, Tasmania, South Australia and the Northern Territory. Western Australia continued to dominate EDR with 58% of the national total, which was a slightly reduced share. In 2004 its EDR fell by 44 t to 3 243 t. South Australia had the second largest EDR. In the Northern Territory, EDR rose by 33 t to 213 t.

Subeconomic demonstrated resources fell by 334 t in 2004. All the reduction occurred in the paramarginal category, which fell by 335 t to 1 102 t. Western Australian paramarginal resources rose by 344 t to 772 t, which was 70% of total paramarginal resources. Increases also occurred in all other jurisdictions except the Northern Territory where paramarginal resources halved. The major reduction in paramarginal resources is attributed to a number of factors but particularly the reclassification of resources following the high gold prices. Submarginal demonstrated resources remained unchanged at 107 t, over half of which is in Western Australia.

Inferred resources rose by 1 125 t due principally to the release of new data for inferred resources at the Olympic Dam (SA) and Bendigo (Vic) deposits. These, together with increases in all other areas except Tasmania and the Northern Territory caused the major growth. Western Australia continued to dominate inferred resources accounting for about 43% of total inferred resources.

The ratio of demonstrated to inferred resources fell sharply from 2.4:1 in 2003 to 1.7:1 in 2004. This is a substantial improvement on the position in 2003 and indicates the availability of inferred resources, which may be upgraded by future exploration to the potentially mineable categories, has improved. However, much of the growth in inferred resource came from one deposit, which suggests that there is still a significant need to increase the level of inferred resources through discoveries.

Accessible EDR

EDR for gold are essentially unencumbered (less than 1% is in any form of restricted area). At Australia's 2004 rate of production, EDR is sufficient for an average 22 years production. If, however, resources only classified as reserves under the JORC Code are considered, they will support only 12 years at the 2004 production rate. This is similar to the 2003 reserve:production ratio. It should be remembered that these are average figures and that there are some operations that may continue after the 22 or 12 year 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 2004 just under 60% of EDR fell into the JORC reserves category compared to 64% in 2003.

Exploration

Gold dominated exploration spending (50.5%) and, at \$397.1 million, was at its highest level since 1998–99. Although in constant 2003–04 dollars, gold remained the dominant commodity sort, the level of spending grew only slightly and was less than in 2000–01 and less than half both the 1996–97 level and the 1987–88 peak.

While gold remained the predominant target in calendar year 2004, its share of total spending fell to 45%. Gold exploration spending was \$414 million in the year, an increase of \$40.3 million. Although Western Australia dominated exploration by attracting \$283.7 million, its share of total gold exploration fell to 68.5%. 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.

Data published by the Canadian company Metals Economics Group (MEG) on company exploration budgets for non-ferrous minerals indicates that intended spending on gold exploration in Australia for the year was US\$323.9 million (A\$438 million using the exchange rate used by MEG). This budget was about 5% higher than actual spending reported by ABS.

The MEG data show that 35.2% of gold exploration budgets were expected to be directed at minesite exploration, while 33.5% was directed to grassroots exploration. The remaining 31.3% 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.

NEW SOUTH WALES

- Alkane Exploration Ltd reported further encouraging drilling from its Tomingley project, which hosts the **Wyoming** gold deposits. Among new targets identified was the McLeans prospect, which has mineralisation in two zones over 1 km strike length and intersections of 4 m @ 3.68 g/t Au, 2 m @ 4.24 g/t Au and 33 m @ 0.54 g/t Au. It also identified Tomingley Two with intersections including 3 m @ 4.93 g/t Au, 24 m @ 1.29 g/t Au and 102 m @ 0.66 g/t Au.
- At **Dargues Reef** south southwest of Braidwood, Hibernia Gold Ltd reported strong drill-intersections including 24 m @ 7.9 g/t Au which included 3 m @ 25.9 g/t Au and 2 m @ 18.0 g/t Au, and, in a new lode, 9 m @ 8.0 g/t Au including 3 m @ 14.6 g/t Au.
- Malachite Resources NL reported that exploration at the Tooloom project in northern New South Wales resulted in an intersection of 150 m of mineralised breccia at the **Phoenix** prospect. The company notes that the breccia appears to be a pipe-like body with surface dimensions of 300 m by 70 m and a depth extent of over 450 m. The average grade for the 150 m intersection was 0.14 g/t Au with individual 1 m sections up to 1.4 g/t Au.

NORTHERN TERRITORY

- Giants Reef Mining Limited reported resources at its **Malbec West** deposit located 900 m west of its Chariot Mine west of Tennant Creek. Total resources of 17 103 ozs are made up of measured resources of 23 100 t @ 17.1 g/t Au, indicated resources of 11 900 t @ 7.9 g/t Au and inferred resources of 11 300 t @ 3.8 g/t Au.

QUEENSLAND

- Strategic Minerals Corporation NL undertook a drilling program at its **Woolgar** project, 100 km north of Richmond, to investigate previously untested epithermal veins. Results included 7 m @ 5.69 g/t Au, 6 m @ 3.96 g/t Au and 2 m @ 12.03 g/t Au at Shanghai, 5 m @ 4.40 g/t Au at Hillview, 2 m @ 4.57 g/t Au and 1 m @ 6.80 g/t Au at Grand Central and 2 m @ 44.5 g/t Au and 2 m @ 46.5 g/t Au at Explorer South.
- At **Manumbar** near Kilkivan, D'Aguilar Gold Ltd reported encouraging results from drilling to test an epithermal system beneath old open pits. Assaying of old core not previously analysed returned 1.3 m @ 14.5 g/t Au and 1.2 m @ 6.61 g/t Au from 104 m and 84.4 m respectively. New drilling returned 6.0 m @ 7.65 g/t Au from 94 m and 0.6 m @ 3.23 g/t Au from 135.2 m.

- At **Mungana** in north Queensland Kagara Zinc Ltd reported an intersection of 58 m of 4.12g/t Au (including 26 m at 8.3 g/t Au within a broader zone of lower grade of 179.7 m at 1.76 g/t Au) porphyry gold mineralisation with a known strike extent of 190 m. Drilling outside of the current published gold resource at Mungana has established a significant extension of the known porphyry gold system.
- Republic Gold Limited's successful drilling program at its **Northcote** project in the Hodgkinson Basin in northeast Queensland saw 85% of 80 holes intersect mineralisation. Significant intercepts include 5.7 m @ 3.32 g/t Au, 8.0 m @ 3.58 g/t Au and 3.0 m @ 3.59 g/t Au.

SOUTH AUSTRALIA

- Exco Resources NL reported and initial resource for the **White Dam** deposit located some 100 km northeast of Woomera, of 258 000 ozs of which 199 800 ozs are oxide resources in the top 30 m of the deposit. The resource (indicated and inferred) is 7.39 Mt @ 1.09 g/t Au.
- Dominion Mining Ltd reported intersecting high-grade mineralisation in drilling to test the M2 and M3 lodes at the **Challenger** mine, which are outside the currently defined reserves. Intersection reported included 15 m @ 16 g/t Au, 2 m @ 92.3 g/t Au, 3.45 m @ 1018 g/t Au and 5.85 m @ 23.6 g/t Au.

TASMANIA

- TasGold Limited intersected low grade gold mineralisation in altered granodiorite at the **Potoroo** prospect in northeast Tasmania. An intersection of 106.5 m @ 0.19 g/t Au included a higher grade interval of 6.9 m @ 1.8 g/t Au.

VICTORIA

- Bendigo Mining Ltd announced a major upgrade in resources at the **New Bendigo** project at Bendigo. The nuggetty nature of gold at Bendigo has meant that, until now, the company has not been able to report a comprehensive resource estimate because of difficulties in establishing confidence in the estimates. Following extensive sampling and assessment work, in December, they were able to announce an inferred resource of 23.5 Mt @ 14.5 g/t Au for 11 M ozs of gold. This is additional to the previously announced indicated resource of 0.72 Mt @ 10 g/t Au for 236 000 ozs.
- Continuing exploration by Ballarat Goldfields NL at the **Ballarat** project yielded more high-grade intersections including 5.3 m @ 7.2 g/t Au, 2.8 m @ 17.5 g/t Au and 2.4 m @ 11.6 g/t Au. Visible gold is present in many of the high-grade intersections.
- Perseverance Corporation reported the discovery of the **Wirrawilla** mineralisation at its Fosterville project east of Bendigo. Wirrawilla, which is under alluvial cover, returned intersections of 10 m @ 2.9 g/t Au, 4 m @ 1.3 g/t Au and 6 m @ 1.4 g/t Au.
- MPI Mines Ltd continued resource definition at the **Golden Gift** deposit at Stawell. Drilling successfully extended mineralisation and encountered strong intersections including 44.1 m @ 11.4 g/t Au, 34.2 m @ 8.0 g/t Au and 1.1 m @ 28.7 g/t Au.
- To the north of the Stawell operation, MPI Mines Ltd continued work on the **Kewell** and **Wildwood** projects. Results from Kewell included 6.3 m @ 10.2 g/t Au, 6.0 m @ 3.0 g/t Au and 1.4 m @ 17.6 g/t Au. At Wildwood results included 6 m @ 4.62 g/t Au, 8 m @ 1.45 g/t Au and 8.5 m @ 3.6 g/t Au.

WESTERN AUSTRALIA

- The discovery of the **Lord Henry** and **Lord Nelson** mineralisation near Sandstone was announced by Troy Resources NL. Lord Nelson has shallow oxide mineralisation with intersections including 10 m @ 7.90 g/t Au from 20 m, 7 m @ 38.60 g/t Au from 48 m and 17 m @ 19.50 g/t Au from 58 m. The Lord Henry mineralisation is also close to the surface and intersections included 5 m @ 6.40 g/t Au from 5 m, 5 m @ 6.40 g/t Au from 22 m and 3 m @ 15.4 g/t Au from 32 m.

- Tanami Gold NL reported more high-grade intersections from the **Coyote** deposit some 200 km southeast of Halls Creek including 9 m @ 43.1 g/t Au, 1 m @ 68.8 g/t Au and 3 m @ 17.5 g/t Au. Some 35 km north of Coyote at the **Sandpiper** and **Kookaburra** prospects drilling has increased confidence in the continuity and grade of mineralisation. At Sandpiper intersections include 13 m @ 2.3 g/t Au and 7 m @ 9.5 g/t Au while at Kookaburra results included 11 m @ 3.3 g/t Au and 15 m @ 2.6 g/t Au.
- De Grey Mining Ltd advised that resource definition drilling at **Wingina** Well, 60 km south of Port Hedland, intersected further high-grade zones. These included 13 m @ 7.97 g/t Au from 62 m and, in the same hole, 32 m @ 2.5 g/t Au. Other results included 2 m @ 16.45 g/t Au from 143 m and 11 m @ 4.4 g/t Au from 168 m.
- At the **Indee** project, 80 km southwest of Port Hedland, Range River Gold Ltd reported further high-grade intersections from the Camel 1 and Withnell deposits including 6 m @ 47.9 g/t Au, 3 m @ 15.7 g/t Au and 10 m @ 8.4 g/t Au. The company indicated that a significant increase in resources at Camel 1 was likely.
- In the Mist Lode at the **Frog's Leg** deposit, 20 km west of Kalgoorlie, Dioro Exploration NL reported high-grade intersections in the lower levels. Results included 32 m @ 12.9 g/t Au, 27 m @ 10.11 g/t Au and 25 m @ 9.70 g/t Au.
- At the **Williamson** prospect, 15 km from its Wiluna plant (7 km south of Wiluna), Agincourt Resources Ltd reported indications that a significant open pit oxide resource may be present with drill results including 53 m @ 3.97 g/t Au, 16 m @ 8.0 g/t Au and 20 m @ 4.4 g/t Au.
- Gleaneagle Resources Ltd reported intersections of 5 m @ 9.82 g/t Au from 32 m, 7 m @ 8.80 g/t Au from 41 m and 11 m @ 5.55 g/t Au from surface at its **Toms** project near the Fortnum plant about 170 km north of Meekatharra.
- Drilling at the **Wallbrook** project, 160 km northeast of Kalgoorlie, by Jackson Gold Ltd, provided the opportunity for increased resources at the Eleven Bells deposits (1.14 Mt @ 1.94 g/t Au) by confirming primary mineralisation continues at depth and maintains thickness. It is of higher grade than the already defined oxide resource. Results include 26 m @ 3.71 g/t Au, 7 m @ 2.87 g/t Au and 6 m @ 3.80 g/t Au.
- Exploration north and south of the old open pit at **Nicholsons Find**, 40 km southwest of Halls Creek, suggests extensions of the mineralised zone. Terra Gold Mining Ltd reported intersections of 3 m @ 33.7 g/t Au from 104 m, including 1 m @ 90.7 g/t Au and 3 m @ 34.5 g/t Au from 103 m including 1 m @ 67.1 g/t Au from the southern prospect. Northern zone intersections were encouraging with the best reported being 3 m @ 2.17 g/t Au from 193 m.
- Drilling at the **Golden Crown** deposit, 20 km east of Halls Creek, by Northern Star Resources Ltd, returned significant high-grade intersections including 4 m @ 284.1 g/t Au from 12 m, 4 m @ 6.01 g/t Au from 48 m and 4 m @ 3.15 g/t Au from 36 m.
- At the **Iron Duke** prospect near Norseman, Tantalum Australia NL confirmed a 100 m strike extension of mineralisation with intersections including 19 m @ 3.85 g/t Au, 5 m @ 11.50 g/t Au and 6 m @ 8.67 g/t Au. Mineralisation is open along strike to both the north and south. At **Surprise**, 800 m north of Iron Duke, drilling returned 7 m @ 3.51 g/t Au, 7 m @ 4.42 g/t Au and 2 m @ 12.39 g/t Au.
- Gondwana Resources Ltd reported encouraging results from its **Centenary** prospect, located some 20 km southeast of Marvel Loch, including 3 m @ 167.2 g/t Au, 1 m @ 36.0 g/t Au and 1 m @ 34.6 g/t Au. Mineralisation is in a strongly sheared amphibolite-BIF zone and the high-grade zones are associated with a quartz-sulphide vein system at the sheared BIF-amphibolite contact.
- At the **Telfer** prospect, near Newcrest's Telfer mine, Mount Burgess Mining NL reported that joint venture partner Barrick Gold of Australia Ltd had results drill intersections including 8 m @ 6.4 g/t Au from 240 m.

Copper-Gold

- WMC Resources Ltd reported an increase of 29.2% in total mineral resources at its **Olympic Dam** mine (SA). Total mineral resources are estimated to be 3.81 billion tonnes @ 1.1% Cu, 0.4 kg/t U₃O₈ and 0.5 g/t Au. Total copper in the resource increased by 7 Mt to an estimated 42.7 Mt, while uranium increased by 230 000 t to an estimated 1.4 Mt. Gold resources have risen by about 24% to an estimated 55.1 Moz.
- Drilling by Minotaur Resources Ltd to test the eastern extension of mineralisation at the **Prominent Hill** deposit in central South Australia continued to yield good intersections. Some were: 41 m @ 2.85 g/t Au, 30 m @ 3.52% Cu and 0.93 g/t Au and 111.5 m @ 1.30% Cu and 0.59 g/t Au. An initial resource estimate was released for part of the deposit. At a 0.5% Cu cut-off grade the inferred resource was 97 Mt @ 1.5% Cu and 0.5 g/t Au but does not include gold resources from areas of gold-only mineralisation.
- Tasman Resources N.L. reported that it had intersected at least 225 m of hematite-altered breccias in a drill hole at its **Marathon South** prospect located 24 km northeast of the Olympic Dam mine. The company reports that the rock is very similar to rocks known from the upper unmineralised parts of the Olympic Dam deposit.
- In the Curnamona Craton (SA), 100 km west of Broken Hill, Havilah Resources NL reported an intersection of 36 m @ 3.1% Cu and 1.0 g/t Au at its **Kalkaroo** prospect. They note that mineable grades of molybdenum are also present. Mineralisation has been traced over 1 400 m around a large arc. The company has drilled 14, 100 m-spaced, drill traverses and each has produced ore-grade intersections.
- Alkane Exploration Ltd reported encouraging first results from its **Galwadgere** prospect in the Wellington project, 15 km southeast of Wellington, NSW. Results include 4 m @ 1.69% Cu and 0.08 g/t Au, 26 m @ 1.09% Cu and 0.26 g/t Au and 47 m @ 0.9% Cu and 1.58 g/t Au.
- Pre-feasibility drilling at Conquest Mining Limited's **Mount Carlton** epithermal project in central Queensland returned intersections including 20 m @ 3.52 g/t Au, 61.3 g/t Ag and 0.65% Cu from 35 m and 25 m @ 2.08 g/t Au, 88.2 g/t Ag, and 1.26% Cu from 67m.

Production

Australian gold production reported by ABARE for 2004 was 259 t, a reduction of 25 t on 2003 production. The Super Pit at Kalgoorlie in Western Australia was again the largest producer with an output of nearly 0.9 Moz. In 2004, Western Australia dominated Australian production with 166 t, which was just under two-thirds of total Australian output.

TABLE 2. Australian gold production 2000 to 2004.

	2000 (t)	2001(t)	2002 (t)	2003 (t)	2004 (t)
New South Wales	18.58	17.10	23.48	27	29
Victoria	4.23	3.50	3.24	4	4
Queensland	37.01	31.89	25.06	26	23
South Australia	2.95	4.31	3.14	5	4
Western Australia	203.74	196.59	187.20	188	166
Tasmania	6.68	6.18	6.05	10	11
Northern Territory	23.14	20.51	17.95	24	22
Australia	296.41	280.08	266.14	284	259

Source: ABARE *Australian Commodity Statistics 2003* and ABARE *Australian Mineral Statistics March and December Quarters 2004*.

ABARE's longer-term outlook is for gold production to rise to 382 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 larger operations such as Telfer and the proposed Boddington mine (WA), Bendigo and Ballart (Vic) and Cowal (NSW).

World Ranking

The USGS estimate of world gold reserves of 42 000 t was slightly lower than in 2003. According to the USGS, South Africa still has the world's largest reserve of gold at 6 000 t (14.2%) but this was a substantial reduction of the 8 000 t held in 2003. The USGS reported a major downgrading of reserves in the USA to 2 700 t (6.4%) compared to 13% in 2003. This revision was based on the closure of mines in the country. Australia has the second largest reserves with approximately 12% of the world's holdings.

GFMS estimate that world gold production in 2004 was 2 464 t, which was 128 t less than in 2003. South Africa with about 14% of world production remained the leading producer. It was followed by the USA, which had an estimated production of 262 t, a reduction of 19 t from 2003. The USA accounted for 10.6 % of world output. Australia followed with 259 t produced in 2004. China's output rose by 6% to 212 t.

Industry Developments

NEW SOUTH WALES

- Barrick Gold Corporation has commenced construction of the **Cowal** gold mining development north of West Wyalong. The Cowal project contains approximately 2.5 million ounces of proven and probable reserves in 63.6 million tons of ore grading 1.3 g/t. Mine and process plant construction is expected to take 21 months, with production commencing in early 2006.
- Newcrest Mining Limited has lodged a Development Application for an extension of its **Ridgeway** mine at depth. If approved, the development will allow production from Ridgeway to continue at existing production rates for over 12 years and remove an additional 53 Mt ore. Newcrest decided to proceed to the next stage of development of the **Cadia East** project which will involve work, over three to four years to support a bankable feasibility study at its Cadia East project. The Cadia East resource has about 18 Mozs of gold and 2.9 Mt of copper. This work will include development of an 11 km decline to facilitate bulk sampling, diamond drilling and the collection of geotechnical data. Development of the decline will start in early 2005 and is to be completed at the end of 2006.

NORTHERN TERRITORY

- Giants Reef Mining Limited commenced in September at its **Malbec West** high-grade deposit near its Chariot mine west of Tennant Creek. The ore is under 5 m of cover and the initial development of a 65 m deep pit will mine up to 15 000 ozs with an expected cash margin of \$300/oz. The company also started mining the small high-grade **Cat's Whisker** deposit, 6 km southeast of Tennant Creek. Cat's Whiskers has 5 500 t @ 24 g/t Au.

SOUTH AUSTRALIA

- Dominion Mining Limited received approvals from the South Australian Government to mine underground resources at its **Challenger** mine. Development commenced in February with construction of a decline and associated surface facilities adjacent to the open pit.

QUEENSLAND

- At Charters Towers, Citigold Corporation announced completion of the second stage of the **Warrior** mine development, which involved the construction of a portal for the decline from the Washington open pit. The third stage will be a 1 km decline to the gold resource and gold production is expected around the end of 2004 at an annual rate of 40 000 ozs.
- SMC Gold Limited started mining at its **Christian Kruck** mine 90 km southwest on Townsville in September.



Mine portal (centre) and surface facilities Cracow gold mine, Queensland (Sedimentary Holdings Ltd).

- Sedimentary Holdings Ltd and Newcrest Mining Ltd continued development of the **Cracow** mine at Cracow in south east Queensland in 2004 with the first ore processed and gold poured in November 2004 after one year production will ramp up to 120 000 ounces gold and 60 000 ounces of silver per year from 300 000 tonnes of 11–14 g/t Au.
- At **Twin Hills** in the northern Drummond Basin in central Queensland, BMA Gold Limited announced indicated and inferred resources of 526 000 t @ 19.3 g/t Au and 435 000 t @ 7.3 g/t Au at its 309 and Lone Sister epithermal gold deposits, respectively. Mine development is expected in 2005.
- Resolute Mining Limited announced new resource figures for their **Ravenswood** projects, Nolans, Sarsfield, and Mount Wright in north-east Queensland with total reserves of 34.0 Mt @ 0.9 g/t Au for 1.025 Mozs in a total resource of 74.9 Mt at 1.3 g/t for 3.15 Mozs.

WESTERN AUSTRALIA

- Newcrest Mining Ltd reported that at **Telfer** all elements of the first processing train had been commissioned in November including the semi-autogenous grinding mill. Ore grade material was being processed to produce a gold-copper concentrate. Over a 24 year mine-life annual production from Telfer is expected to be 800 000 oz Au and 30 000 t Cu. Current in situ resources at Telfer are 26 Mozs Au and 0.96 Mt Cu.
- Metex Resources Ltd commenced trial mining of **Whisper** trial pit started in the June quarter as part of a feasibility study on the Whisper resource, which was scheduled for completion by the end of 2004.
- At the East Kundana project Tribune Resources NL announced that the **Raleigh** underground mine would be developed. The mine is expected to produce 487 000 ozs over a seven year mine life with the ore being processed at the Paddington plant.
- Dioro Exploration NL announced the first gold pour at the **Frog's Leg** project. The initial operation will yield 112 000 oz over 14 months. A pre-feasibility study confirmed an underground resource of 1.8 Mt @ 5.4 g/t Au would support a four year operation.



Gold ore stockpile at Kanowna Belle mine, Western Australia (Placer Dome Inc.)

- Reed Resources Ltd announced that it would develop the high-grade **Sand George** deposit at Comet Vale, 100 km north of Kalgoorlie (WA). The company expects to recover 65 200 ozs over a two-year mine life.

Iron Ore

Iron is the second most abundant metal after aluminium making up about 5% by weight of the Earth's crust. Iron is almost always found as an iron oxide, for example, hematite ($\text{Fe}_2\text{O}_3 - 69.9\%\text{Fe}$) and magnetite ($\text{Fe}_3\text{O}_4 - 74.2\%\text{Fe}$). About 98% of iron ore is used in the iron and steel industry with the remainder mainly used in coal washeries and cement manufacturing. Iron, in the form of steel, is used 20 times more than all the other metals put together.

The iron ore industry in Australia is a major export industry dominated by the Western Australian operations of Rio Tinto and BHP Billiton. Other locally important iron ore projects include Koolyanobbing, Cockatoo Island, Talling Peak (WA), Middleback Ranges (SA) and Savage River (Tas). Minor production occurs at Breadalbane (NSW), Tallawang (NSW) and Kara (Tas).

Resources

In 2004, EDR increased by 17.7% to 14.6 Gt. This was mainly due to price increases from which magnetite deposits were reclassified as economic, for example, Iron Magnet, George Palmer, Mt Gibson and Southdown. There were also increases in Hamersley Iron resources and Christmas Creek was included for the first time. Western Australia has almost all of Australia's EDR with about 92% occurring in the Pilbara district.

With the reclassification of demonstrated magnetite deposits as economic, paramarginal demonstrated resources decreased by 80% to 0.2 Gt. Subeconomic demonstrated resources decreased 2.0% to 1.9 Gt following updated resources being reported for Talling Peak. Inferred resources increased by 0.9% to 16.9 Gt due largely to the inferred resources at Christmas Creek, Mt Lewin, Claytons Hammer and Minister North offsetting decreases at Yandicoogina, undeveloped Hamersley Iron deposits and

Mt Gibson. Western Australia has just under 90% of Australia's total identified resources of iron ore with over 80% occurring in the Pilbara district.

Accessible EDR

Almost all EDR is accessible except for the remaining resource at Orebody 23 (18 Mt) in the Newman District and 30% of the Windarling resource, which have both been quarantined for environmental reasons. The resource life of the accessible EDR of 14.6 Gt is around 65 years.

JORC Reserves

Over 30% of accessible EDR, or 4.6 Gt, is JORC compliant. The resource life of accessible JORC reserves is about 20 years. Around 30% of EDR is in the JORC reserves category.

Exploration Expenditure

ABS data indicate that exploration expenditure for iron ore in 2004 totalled \$97.9 million, an increase of over 85% from \$52.1 million in 2003. Detailed data on spending are not available from ABS but most is likely to have been spent in Western Australia.

Production

ABARE reported that Australia's iron ore production in 2004 was 231.0 Mt (212.9 Mt in 2003) with 97% produced in Western Australia. The remaining production came mainly from South Australia and Tasmania. Exports in 2004 totalled 210.3 Mt (187.3 Mt in 2003) with a value of \$6 073 million. ABARE has projected that Australia's iron ore production will reach 341 Mt in 2009–10.

World Ranking

Australia has some 9% of world EDR of iron ore and is ranked fifth after Ukraine (19%), Russia (16%), China (13%) and Brazil (13%). In terms of contained iron, Australia has about 11% of the world's EDR and is ranked fourth behind Russia (18%), Brazil (18%) and Ukraine (11%).

Australia produces around 18% of the world's iron ore and is ranked third behind China (22%) and Brazil (18%).

Industry Developments

WESTERN AUSTRALIA

Hamersley Iron (100% Rio Tinto): Eastern Range mine was officially opened in April 2004. Under the terms of the joint venture agreement between Hamersley Iron and Baosteel Group 200 Mt of iron ore will be supplied at 10 Mtpa over 20 years. The capacity of the Yandicoogina mine is being expanded from 24 to 36 Mtpa at a cost of US\$200 million. Completion is scheduled for early 2005 and pre-feasibility studies are being undertaken into further expansion. Feasibility studies are progressing on expansion of production at Tom Price and Marandoo and mining the Nammuldi and Brockman No 4 deposits.

Expansion of the Port of Dampier from 76 to 116 Mtpa commenced in early 2004 with completion scheduled for late 2005. Stage 1 work will expand port capacity to 95 Mtpa and focus on Parker Point. Included in the expansion program is a new gas-fired power plant at Paraburdoo and a 95 km rail line duplication. After six years of negotiation the Eastern Guruma Indigenous Land Use Agreement was registered in March 2004. Hamersley Iron will contribute to a Trust and provide a range of long term community benefits to Aboriginals with traditional ties to the area.

Robe River Associates (53% Rio Tinto): At West Angelas mine, Marra Mamba ore production began in April 2002 at a rate of 7 Mtpa and by 2004 capacity reached 20 Mtpa. Construction of an expansion to 25 Mtpa commenced in early 2004 and is expected to be completed by mid-2005. Project teams have been assembled to study options for significant expansion of Robe River's production capacity, including an expansion at Cape Lambert beyond the current 55 Mtpa. The Pilbara Iron company was



Iron ore stockpiles at East Intercourse Island, Western Australia (Pilbara Iron Pty Ltd).

established in 2004 to manage all mining, rail, port and power infrastructure together with the provision of corporate and site services on behalf of Hamersley Iron and Robe River Associates.

BHP Billiton: Upgrade and expansion of the port and railway capacity from 85 to 100 Mtpa, a project known as Products and Capacity Expansion, was completed in early 2004. By the end of year, the initial Rapid Growth Project (RGP1) had further expanded capacity to 110 Mtpa. The second Rapid Growth Project 2 (RGP2) is designed to expand capacity from 110 to 118 Mtpa by the second half of 2006. A feasibility study due for completion in early 2005 is examining a two stage capacity expansion to 145 Mtpa costing US\$1 billion.

As part of RGP1, Mining Area C production capacity was increased from 15 to 23 Mtpa. RGP2 includes the development of Orebody 18 at an initial 8 Mtpa and plant modifications at Orebody 25. At Yandi, the “Western 4” life extension project will provide up to 15 Mtpa of Lower Channel Iron Deposit ore by the second half of 2005.

Portman Ltd: Mining commenced in early 2004 at the \$23.2 million Mount Jackson and Windarling expansion project. Delivery of ore to Koolyanobbing commenced in April 2004 after a 100 km ore haulage road was completed. A new \$55 million expansion project to lift production from 5 to 8 Mtpa commenced in October 2004. When completed in late 2005, production will consist of 6 Mtpa of a standard product and 2 Mtpa of a lower iron content and higher phosphorous product. At Cockatoo Island full production recommenced after the Stage 2 seawall was completed in August 2004.

Mount Gibson Iron Ltd: Operations commenced at Tallering Peak in late 2003 with the first hematite shipment from Geraldton to China in February 2004. The company plans to mine at a rate of 2.5 Mtpa for about six years before relocating operations to the Mt Gibson hematite deposit, where mining is scheduled to continue for another five years. Another proposal includes developing a mine at Koolanooka South by late 2006 to produce 2.5 Mtpa of magnetite concentrate for a pellet plant in Longtan, China. A second 2.5 Mtpa mine at Wolla Wolla is scheduled to produce 12 months later, with the magnetite concentrate destined for the pellet plant in Longtan.



Crushing plant at Talling Peak iron ore mine northeast of Geraldton, Western Australia (Mount Gibson Iron Ltd).

Aztec Resources Ltd: An \$8 million bankable feasibility study to be completed in early 2005 is evaluating the recommencement of mining on Koolan Island, 130 km northwest of Derby. Mining is proposed to commence by mid-2006 with an initial capacity of 2 Mtpa over 15 years. The project includes a new shiploader and jetty to accommodate Cape size vessels (up to 190 000 t).

Hope Downs Management Services (includes **Hancock Prospecting**): The \$1.65 billion Hope Downs project involves mine construction, 370 km of rail line and infrastructure at Port Hedland. The mine will be based on the Hope Downs 1 Marra Mamba deposit 100 km northwest of Newman and production is planned to commence in 2007 at a rate of 5 Mtpa and increase to 25 Mtpa within five years.

Fortescue Mining Group Ltd (FMG): Up to seven drilling rigs operated in the Chichester Range delineating iron ore resources during 2004. A definitive feasibility study of the Chichester Range resources is due for completion in early 2005. FMG is proposing to spend \$1.85 billion to construct a mine, 520 km of multi-user railway to Port Hedland and multi-user port facilities. Construction of a 45 Mtpa operation is proposed to commence in mid-2005 and be completed in early 2007. In late 2004 the Australian Government granted Major Project Facilitation status to FMG's Pilbara Iron Ore and Infrastructure Project.

Midwest Corporation Ltd: Plan to ship 1.1 Mt of existing hematite iron ore fines from Koolanooka over 14 months from late 2005. The \$16 million capital cost includes a storage shed at Geraldton, rail wagons and siding, construction and upgrading of haul roads and site infrastructure. Midwest is also planning to recommence mining at Koolanooka and Blue Hills at a rate of 1 Mtpa over three years. A scoping study is due for completion in 2005 on the proposed Koolanooka magnetite project. A pre-feasibility study is to be completed to determine the viability of the proposed Weld Range direct shipping of hematite ore project.

Grange Resources Ltd: A Scoping study on the Southdown magnetite deposit determined that ore could be mined at a rate of 17.8 Mtpa and a magnetic separation plant produce 6.5 Mtpa of concentrates at 69% Fe. The concentrate could then be transported to Albany in a slurry pipeline

and then exported to a pellet plant in southeast Asia. A bankable feasibility study commenced in late 2004 and is expected to take about 12 months to complete. If the \$400 million project proves viable construction could commence in 2006 with exports commencing in 2008.

Mineralogy Pty Ltd: The \$1.8 billion Fortescue iron ore project consists of a mine based on the George Palmer deposit, a pellet plant and a port at Cape Preston. Mineralogy is proposing to produce 5 Mtpa of concentrate and 5 Mtpa of pellets over 25 years. Construction is planned to start in 2005 with the first shipments to start by late 2007.

Murchison Metals Ltd: The \$14.5 million Jack Hills iron ore project is scheduled to commence in late 2005 at a rate of 1.0 Mtpa. Direct shipping grade ore will be trucked by road trains 580 km to the Port of Geraldton for export. A second stage consists of a 15 to 20 Mtpa operation and includes the construction of railway and port infrastructure at a cost of \$400 to \$500 million.

Gindalbie Gold Ltd: A scoping study is due for completion in early 2005 on the Mt Karara magnetite deposit. The deposit could potentially support a 2 Mtpa magnetite concentrate operation over 20 years.

Resource Mining Corporation: The company is seeking to prove sufficient reserves at the Argyle iron ore deposit (previously known as Pompeys Pillar) to sustain an operation of direct shipping ore that would be trucked 170 km to Wyndham for export.

SOUTH AUSTRALIA, TASMANIA AND NORTHERN TERRITORY

OneSteel Ltd: In August 2004, Onesteel announced the start of Project Magnet, which is planned to extend the life of the South Australian Whyalla operation from 2020 to at least 2027. The \$250 million project will convert the Whyalla Steelworks to producing steel from magnetite rather than hematite. The project, which is scheduled to be completed in mid-2006, includes a mine cut back, magnetite concentrator, 62 km of slurry pipeline and conversion of the pellet plant. Iron ore and production will rise from 3 to 9.5 Mtpa and includes exports of 3 Mtpa of hematite and 320 ktpa of pellets.

Ivanhoe Mines Ltd: At Savage River the North and Centre Pits commenced ore production. The South Pit ceased production in mid-2004 and work continued on an evaluation of an underground block cave operation in the North Pit. The open-pit mine is scheduled to reach the end of its life in 2007 with pellet production finishing in 2009.

Territory Iron Ltd: The company is seeking to upgrade resources at Frances Creek to allow the development of an operation that would rail iron ore 200 km to Darwin for export.

Industry Developments – Iron and Steel

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

- The **Boodarie** hot briquetted iron plant near Port Hedland. After an explosion in May 2004 the plant was placed on care and maintenance in November until its long term future is determined.
- Construction of the \$420 million **Hismelt** DRI processing plant at Kwinana was largely completed by the end of 2004 with commissioning due to commence in early 2005. The plant is designed to process 1.3 Mtpa of high phosphorous iron ore to produce 800 ktpa of 96% iron content pig iron.
- Pig iron production in blast furnaces at Port Kembla and Whyalla.
- Steel production at Port Kembla, Whyalla, Rooty Hill, Mayfield and Laverton North.
- Compact Steel is planning a 1.4 Mtpa steel plant costing \$1.5 billion at Rockingham in Western Australia.
- Protech Steel is investigating a \$600 million steel processing mill to produce mainly coated steel products in Newcastle.
- Specialty Steels propose to construct a steel mini-mill capable of producing up to 260 000 tpa of stainless and specialty steel products in the Swanbank Enterprise Park near Ipswich.

- Westralia Iron and Steel Corporation Ltd has proposed a 1.5 Mpta pig iron plant for Collie in Western Australia.
- Aviva Corporation is proposing to construct a DRI plant at Geraldton based on coal from Eneabba and iron ore from the Mid-West Region of Western Australia

Lithium

Lithium is a silvery grey metal with a density about half that of water. Sons of Gwalia's Greenbushes mine in Western Australia is the world's second largest producer of lithium minerals. Greenbushes products have a range of uses that include production of specialty glasses, ceramics and ceramic glazes, glass bottles. Its ore (predominantly spodumene $\text{Li}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2$) is also a feedstock for the production of lithium carbonate in the chemical industry.

Resources

All of Australia's lithium resources are in Western Australia and the Greenbushes deposit, the world's largest and highest grade spodumene deposit, in the southwest of the state accounts for all EDR. EDR increased marginally in 2004 to 170 000 t, due mainly to a reassessment of resources. Other resource classifications remained unchanged.

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, as well as increased resource definition at Greenbushes, substantial exploration expenditure in Australia is unlikely in the near future.

Production

Chile is the largest producer of lithium minerals in 2004, followed by China and potentially Australia. 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 minerals on the world markets.

World Resources

According to estimates published by the USGS, Chile holds approximately 73% of the world's lithium resources followed by China with 13%, Brazil with 4.5% and Australia 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, now the dominant feedstock for lithium carbonate production, are produced dominantly by Chile. Canada, China and Australia have the most significant resources of lithium minerals.

World production of lithium in 2004 from Geoscience Australia and USGS data is estimated to be 15 500 t of contained lithium, a slight increase since 2003. Chile with production of 41% remained the world's largest producer, followed by China (17%), Australia (10% for half year), and Argentina (8%). Information on US and Russian production is not published by the USGS for commercial reasons.

Industry Developments

Sons of Gwalia went into receivership in 2004. Production of lithium from Greenbushes, however, is expected to continue.

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 was virtually unchanged at 344 Mt in 2004, with only a slight reduction through production from the Kunwarara mine in Queensland. South Australia has the largest holding of EDR with a global resource of 579 Mt of magnesite of which 235 Mt is classified as EDR.

Queensland has the second largest inventory of EDR. The bulk of this is at Kunwarara (70 km northwest of Rockhampton), where Australian Magnesium Corporation Ltd has an inferred global resource of 1 200 Mt of magnesite-bearing material. Within this resource, which contains an inferred resource of 500 Mt of magnesite, the company has identified several high-grade magnesite zones, which are classified by Geoscience Australia as EDR. The Kunwarara deposit contains substantial accumulations of very high-density "bone-type" magnesite, which is characterised by nodular and cryptocrystalline structure and low iron-content.

The Arthur River deposit in Tasmania has indicated resource of 26 Mt of magnesite, which is classified as EDR. Magnesite in this deposit is typically around 42.8% MgO and is part of a much larger resource of 195 Mt in the Arthur-Lyons River area (about 53 km south of Burnie).

Subeconomic demonstrated resources of 57 Mt of magnesite are unchanged from 2003. All of these resources occur in Queensland and Tasmania. Inferred resources are also the same at around 930 Mt, with Queensland accounting for 50% followed by South Australia (31%) and Tasmania (16%).

Accessible EDR

All magnesite EDR is accessible for mining.

JORC Reserves

Around 10% 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 the rate of production in 2004, magnesite resources in the JORC Code reserves categories are adequate for 64 years.

Exploration

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

Production

In 2004, Australian Magnesium Corporation Ltd mined 3.83 Mt (3.02 Mt 2003) of crude magnesite ore at Kunwarara, which was beneficiated to produce 543 306 t of magnesite (470 038 t in 2003). This produced 86 854 t of dead-burned magnesia (108 190 t in 2003), 62 299 t of calcined magnesia (56 143 t 2003) and 25 324 t of electrofused magnesia (25 064 t in 2003).

World Ranking

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

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

Industry Developments

After initial investigations of the feasibility of establishing a magnesium smelter project in Queensland, Magnesium International decided on a site in Egypt.

Manganese Ore

Manganese is the twelfth most abundant element in the Earth's crust and in nature occurs most commonly as the minerals pyrolusite (MnO_2) and rhodochrosite (MnCO_3). It is the fourth most used metal after iron, aluminium and copper. Over 90% of the world's production of manganese is utilised in the desulphurisation and strengthening of steel. Manganese is also used in the manufacture of dry batteries, as a colorant, and as an ingredient in plant fertilisers and animal feed.

In Australia there are two operating manganese mines, **Groote Eylandt** (NT) and **Woodie Woodie** (WA). A third is under construction at Bootu Creek (NT). Manganese ore is processed in plants at Bell Bay (Tas) and Newcastle (NSW).

Resources

In 2004 Australia's EDR of manganese ore increased by 7.6% to 133 Mt mainly due to the addition of Bootu Creek resources and an increase in resources at Woodie Woodie. Paramarginal demonstrated resources increased 22% to 28 Mt through the addition of Bootu Creek low grade resources. Subeconomic demonstrated resources remained unchanged at 167 Mt. Inferred resources decreased by 32% to 135 Mt, mainly as result of a revised orebody model and volume conversion factor (ore specific gravity) applying at Groote Eylandt.

Accessible EDR

All manganese ore EDR (133 Mt) is accessible. The resource life is about 20 years on current rates of production of beneficiated manganese ore.

JORC Reserves

Manganese ore JORC reserves are 95 Mt (71% of accessible EDR). All JORC ore reserves are in the Groote Eylandt deposit, where resource life based on these reserves is about 14 years at the current rate of production of beneficiated manganese ore.

Exploration Expenditure

Data relating to exploration expenditure for manganese are not published by ABS on either a state or national basis. Consolidated Minerals budget \$6 million per annum on manganese exploration.

Production

In 2004 production of manganese ore at Groote Eylandt totalled 2.73 Mt and at Woodie Woodie 0.65 Mt. ABARE report that Australia produced 3.38 Mt of beneficiated manganese ore (2.5 Mt 2003). Exports for 2004 totalled 2.82 Mt (2.1 Mt 2003) valued at \$402 million (\$312 million 2003).

World Ranking

Australia has 11% of the world's EDR of manganese ore and is ranked fourth behind Ukraine (35%), India (21%) and China (17%). In terms of contained manganese, Australia has 15% of the world's EDR and is ranked third behind Ukraine (33%) and India (21%). USGS shows India's EDR increased significantly from 15 to 93 Mt of contained manganese metal.

Australia produces 13% of the world's manganese ore and is ranked third behind China (16%) and South Africa (16%).



Road train transportation of manganese ore from Woodie Woodie mine, Western Australia (Consolidated Minerals Ltd).

Industry Developments

On Groote Eylandt, GEMCO extracts ore by open-pit mining, which is closely followed by rehabilitation. The ore is trucked to a central processing plant, which produces a lump and fine product. Lump and fines are shipped from Milner Bay to markets in Australia and overseas.

Woodie Woodie, located 400 km southeast of Port Hedland, was re-opened in the late 1990s and since then 8 Mt of additional resource has been defined. In 2004, \$6.5 million was expended to increase production from 600 to 800 ktpa by constructing an additional heavy media separation plant, modifying existing crushing plant and increasing site accommodation. Consolidated Minerals is looking to increase production a further 200 ktpa to 1 000 ktpa by mid-2005.

In October 2004, construction of a \$24 million open-pit mine commenced at Bootu Creek, 110 km north of Tennant Creek. The project is scheduled to produce 415 ktpa of lump and 130 ktpa of fine products from mid-2005. The products are to be trucked about 60 km to the Darwin railway and from there transported some 900 km to a bulk handling facility at Darwin's East Arm Port. The project has a five year mine life with a possible further 10 years based on additional resources.

HiTec Energy Ltd is proposing to produce electrolytic manganese dioxide (EMD) at the Cawse nickel operation, 55 km north of Kalgoorlie. A feasibility study completed in 2004 concluded that a \$57 million first stage could produce 14 ktpa of EMD. In late 2004, HiTech decided on initial production of 23 ktpa with the potential to produce 33 ktpa. Tailings from Woodie Woodie would be leached in the OMG Cawse Nickel Operation's autoclave together with OMG's nickel/cobalt/manganese ores and ores from other sources. After removal of iron, nickel and cobalt, the process liquors would be passed to HiTec for electrolytic removal of the manganese with the residual liquor passed back to OMG for water recovery and tailings separation. Hitec plan to commence the project in the second half of 2005 with a 12 month construction and commissioning period.

Mineral Sands

The principal components of mineral sands are the titanium minerals – rutile (TiO_2) and ilmenite (FeTiO_3), and zircon (ZrSiO_4). Rutile and ilmenite are mainly used in the production of titanium dioxide pigment with a small portion, less than 4% of total titanium mineral production, typically rutile, used in making titanium sponge metal. Zircon is used as an opacifier for glazes on ceramic tiles, in refractories and for foundry industry.

Resources

The EDR of ilmenite increased 4% to 217.2 Mt in 2004, from 208.8 Mt in 2003.

About 62% of Australia's EDR of ilmenite is in Western Australia, 24% in Queensland and the rest in New South Wales (7%), Victoria (6%) and South Australia (2%). A small quantity of ilmenite EDR (33 000 t) is reported for the first time for Northern Territory in early 2005 but this figure is not included in the 2004 calendar year totals.

The EDR of rutile (which includes leucoxene in Western Australia) declined by 5.2% from 21.3 Mt in 2003 to 20.2 Mt in 2004. Queensland has the largest share of Australia's rutile EDR with 35% followed by Western Australia with about 22.8%. New South Wales accounts for about 22.2% of the resources with Victoria holding 18.7% and South Australia 1.3%.

Australia's EDR of zircon decreased by 6.8% from 32.2 Mt in 2003 to 30 Mt in 2004 with Western Australia and Queensland accounting for 76.8% of total zircon EDR. The balance of zircon EDR was distributed among New South Wales (11.4%), Victoria (8.3%) and South Australia (3.4%).

Subeconomic demonstrated resources of ilmenite, rutile and zircon remained unchanged in 2004 at 51 Mt, 12 Mt and 19 Mt, respectively. Over 99% of these resources are recorded in the paramarginal category and are associated with the WIM deposits in the Murray Basin in Victoria. The WIM deposits also contain 14.38 Mt of leucoxene.

Inferred resources of ilmenite increased to 118.9 Mt from 106.8 Mt in 2003. Most of this increase was in Victoria and to a lesser extent in Western Australia. Victoria has the largest proportion of inferred ilmenite resources with 49% followed by New South Wales with 18%, Western Australia 17% and Queensland, with 10%.

Inferred resources of rutile rose by 12.6% with increases of 21% in New South Wales and 12% in Victoria. Victoria has the largest share of inferred rutile resources with 55% of the total followed by New South Wales (32%) and South Australia (8%).

Inferred resources of zircon increased by 23.6% with the largest increases in South Australia, which rose by more than 260%, followed by Victoria and Western Australia. Victoria is the main holder of zircon inferred resources with 54% of the Australian total, followed by New South Wales (17%), South Australia (15%) and Western Australia (7%).

In addition to ilmenite, rutile and zircon, Australia also had resources of leucoxene reported in 2004. Leucoxene resources comprise 3.5Mt of EDR, 17.7Mt of paramarginal resources and 15.5Mt of inferred resources. About 90% of the leucoxene EDR is in Western Australia and Queensland.

Accessible EDR

A significant portion of mineral sand EDR are in areas quarantined from mining. These areas are largely within national parks and Geoscience Australia estimates that some 17% of ilmenite, 28% of rutile and 27% 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, 27% rutile and 26% zircon AEDR comprise JORC Code reserve. The remaining represents resources assessed by Geoscience Australia from the measured and indicated categories of industry reported mineral resources, as defined under the Code and other classification systems used by companies not listed on the Australian Stock Exchange.

Duration of Resources

At Australia's 2004 rates of production, AEDR of ilmenite, rutile and zircon are sufficient for an average of 94, 90 and 49 years respectively. Resources in the JORC Code reserves categories, however, are adequate for only 22 years for ilmenite, 24 years for rutile, and 13 years for zircon.

Exploration

According to quarterly ABS figures, expenditure on exploration for mineral sands in 2004 was estimated at \$24.7 million (compared with \$26.3 million in 2003). This represents a decrease of about 6% over the previous year.

Production

In 2004, Australia produced 1.93 Mt of ilmenite, 162 000 t of rutile, 44 000 t of leucoxene and 441 000 t of zircon (compared with 2.01 Mt of ilmenite, 173 000 t of rutile, 58 000 t of leucoxene and 462 000 t of zircon in 2003). The bulk of Australia's rutile and zircon production is exported compared to about 39% for ilmenite. The remaining ilmenite is upgraded to synthetic rutile containing about 92–94% TiO₂. In 2004, Australia produced 720 000 t of synthetic rutile (compared with 666 000 t in 2003).

World Ranking

According to Geoscience Australia and USGS data, Australia has the world's largest EDR of rutile and zircon with 39%, and 41%, respectively and has the second largest share of ilmenite at 20% behind China (35%). Other major country rankings include India (15%), South Africa (11%) and Norway (10%) for ilmenite; South Africa (15%) and India (14%) for rutile; and South Africa (29%) and Ukraine (8%) for zircon.

In 2004, world production of ilmenite increased by 11% to 8.97 Mt, rutile decreased by 4.8 % to 400 kt, and zircon increased by 20% to 1 070 kt. Australia is the largest producer of rutile with about 41% of the world production followed by South Africa with 38% and Ukraine with 17%. It is the second largest producer of ilmenite with 22% after South Africa with 24% of the world's production and also the second largest producer of zircon with 41% after South Africa with 43%.

Industry Developments

In 2004, Australia produced 1.93 Mt of ilmenite, 162 000 t of rutile, 44 000 t of leucoxene and 441 000 t of zircon. Companies that produced heavy mineral sands during 2004 were Iluka Resources Ltd, BeMax Resources Ltd, TiWest joint venture, and Doral Mineral Sands Pty Ltd all in Western Australia and Consolidated Rutile Ltd (Queensland). Potential greenfields mineral sands project include BeMax Resources Ltd's Pooncarrie mineral sands project in New South Wales, Iluka's Douglas project in Victoria, Australia Zircon NL's Mindarie project in South Australia and the Coburn project of Gunson Resources Ltd in Western Australia.

Iluka Resources Ltd operated open-pit mines at Eneabba and Capel and two synthetic rutile plants and a zircon finishing plant at Geraldton (WA). 2004 production was 66 507 t of rutile, 496 000 t of synthetic rutile, 982 000 t of ilmenite, 283 000 t of zircon, and 12 271 t of the proprietary product Hiti91. The company is the second-biggest titanium dioxide feedstock producer in the world behind Rio Tinto, and is the largest zircon producer. Rutile and zircon production declined in response to lower grades being mined at Eneabba during the year and the mining of remnants at Capel during the first half of the year. Improvements to synthetic rutile kiln utilisation and throughput levels at north-Capel led to record level of production of synthetic rutile. During the period under review,



Exploration for mineral sands in the Eucla Basin, South Australia (Iluka Resources Ltd).

Iluka committed to invest \$12.6 million to modify the Narngulu separation plant and acquire mobile equipment to process intermediate and tailings stockpiles at Narngulu and Eneabba. The processing of stockpile material commenced in early 2005 and it is expected to deliver approximately 140 000 t of additional zircon production over a 32 month period. Iluka also committed to invest A\$63 million to establish two new mining and concentrating operations in Western Australia, which are scheduled commence production by mid-2005. One will be located at Wagerup with production being processed at the north-Capel dry plant and will produce approximately 750 000 t of sulphate ilmenite and 55 000 t of zircon and hyti (Yanis is this high Ti) products over a two and a half year period.

Iluka's new operation is to be located at Gingin. With production being processed at the Narngulu dry plant, it will produce about 600 000 t of ilmenite for use as synthetic rutile feedstock, 310 000 t of chloride grade ilmenite, 75 000 t of rutile and 65 000 t of zircon. Iluka also commenced construction of the \$270 million Douglas project in the Victorian part of the Murray Basin. In 2004 the company discovered zircon-rutile-ilmenite deposits, Ambrosia and Jacinth, in the Eucla Basin in South Australia.

The TiWest JV (Ticor Ltd 50%, Kerr McGee Corp 50%) operates an integrated titanium dioxide project, 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 in Western Australia. 2004 production totalled 472 000 t of ilmenite, 76 000 t of zircon, 35 000 t of rutile, 21 000 t of leucosene, 224 000 t of synthetic rutile and 107 100 t of TiO₂ pigment. Current reserves for the Cooljarloo operations are 173 Mt of ore averaging 2.7% heavy mineral sands.

To the end of 2004, Consolidated Rutile Ltd's (CRL) operations at the Yarraman and Enterprise mines on North Stradbroke Island produced 59 856 t rutile and 43 292 t zircon, representing a combined improvement of 35 % over 2003 production. The increase was partly due to the introduction of supplementary dry mining operations in late 2003. Ilmenite production increased marginally by 1% to 124 776 t. At the Enterprise mine, a major upgrade was carried out on the Ibis dredge and concentrator and the operation is now mining through very low-grade material towards the Enterprise orebody of some 1.2 billion tonnes, which it is expected to reach in late 2005.

In 2003, Austpac Resources NL signed a memorandum of agreement with CRL for supply of 70 000 t of high-chrome ilmenite concentrate to a 30 000 tpa high-grade synthetic rutile (>97% TiO₂) plant proposed by Austpac for the eastern seaboard of Australia. Austpac also signed a memorandum of agreement with Iluka Resources Limited, whereby Iluka agreed to purchase all the synthetic rutile produced from the proposed plant. Both contracts are subject to the successful completion of a bankable feasibility study by Austpac. Austpac started an upgrade of its pilot plant at Kooragang Island, Newcastle, to a fully integrated demonstration plant with a nominal capacity of 1 500 tpa of high grade synthetic rutile. The scale-up factor from the demonstration plant to the 30 000 tpa synthetic rutile plant will be less than 25:1. Detailed process data from the demonstration plant is to be used to complete the final plant design and obtain capital and operating cost estimates for the 30 000 tpa plant.

During 2004, BeMax Resources NL completed the purchase of the mineral sands assets of Sojitz Corporation (formerly known as Nissho Iwai Corporation) and Sons of Gwalia in Western Australia and in the Murray Basin (NSW and Vic).

Heavy mineral resources/reserves controlled by BeMax Resources NL 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. In the Murray Basin, the heavy mineral sand reserves (JORC category) controlled by BeMax amount to 187 Mt containing 5.38 Mt heavy minerals grading at about 46% ilmenite, 20% leucoxene, 12.% rutile and 10% zircon. During 2004, BeMax completed acquisition of the minerals sands assets of Sojitz Corporation (formerly known as Nissho Iwai Corporation) and Sons of Gwalia Limited.

BeMax commenced the development and construction phase of the Pooncarie Project in early 2005 with first heavy mineral sales scheduled in the first half of 2006. The project, located in the northern part of the Murray Basin of New South Wales, consists of the Ginkgo and Snapper deposits and contains in excess of 10 Mt of heavy minerals with a mine life of over 20 years. It will initially consist of three main operations:

- the Ginkgo mine site near Pooncarie comprising a refurbished dredge and an upgraded wet concentrator plant both relocated from Western Australia, and a heavy mineral concentrate processing facility for magnetic separation of ilmenite, leucoxene and rutile/zircon fractions, from where
- the heavy mineral concentrates will be transported to Broken Hill, about 240 km north northwest of Pooncarie, where a first stage mineral separation plant (MSP), a leucoxene plant and a wet gravity plant (for upgrading rutile/zircon fraction) are being constructed, and
- an existing MSP with upgraded rutile/zircon circuits near Bunbury in Western Australia, which will process non magnetic material being railed and shipped from Broken Hill.

The heavy mineral reserves controlled by BeMax in the south west region of Western Australia amount to 17 Mt with about 1.95 Mt heavy minerals grading at about 84% ilmenite, 2.6% leucoxene and 9% zircon. Current mining operations comprise the dry mining operations at Tutunup and Ludlow. The Ludlow mine was commissioned in late 2004 and commissioning of the concentrator began early in December, with site operations on a seven-day basis starting towards the end of the period. BeMax is pursuing permitting for mining in the Gwindinup area while decommissioning and rehabilitation activities continued at the Jangardup site during the quarter and the rehabilitation of the Yarloop and Sandalwood mine sites commenced.

Australia Zircon NL's Mindarie deposits, 148 km east northeast of Adelaide, contain one of the world's highest ratios of premium-grade zircon to titanium minerals. The company's tenements contain measured and measured and indicated resources estimated at 126.5 Mt at 3.2% heavy minerals consisting of approximately 18.6% zircon, 7.2% leucoxene, 5.0% rutile and 62.5% ilmenite. The mining plan is based on 61 Mt of ore averaging 4.1% heavy minerals corresponding to annual production levels of 43 000 tonnes per annum (tpa) of zircon, 8 200 tpa rutile, 7 200 tpa leucoxene

and 85 000 tpa of ilmenite over a mine life of 10.8 years. All of the project's planned output will be contracted under long term supply arrangements with off-take partners for the first five years of the mine life.

Australian Zircon NL is also earning an 80% participating interest in its WIM 150 Joint Venture with Austpac Resources NL. Metallurgical testwork is being carried out to recover a zircon product from the WIM 150 heavy mineral deposit that would be suited to the premium ceramic grade market.

Olympia Resources NL announced an upgraded heavy mineral resource status for its Keysbrook deposit to 64 Mt of measured, indicated and inferred tonnes of mineral sand at 2.6% heavy minerals for 1.66 Mt of heavy minerals at a cut-off grade of 1.5%. The resource is reported to contain proved and probable reserves of 41 Mt of mineral sand at 2.7% heavy minerals containing 1.174 Mt of heavy minerals. The company is anticipating completing a feasibility study on the deposit by mid-2005.

In other developments during 2004, Gunson Resources Limited announced, for their Coburn Project in Western Australia, an indicated resource of 250 Mt with 1.4% heavy minerals containing about 3.5 Mt heavy minerals grading at 46% ilmenite, 5% rutile, 6% leucoxene and 23% zircon with additional 460 Mt of inferred resource at 1.4% heavy minerals. The company completed a bankable feasibility study in late 2004 and construction is anticipated to commence once mining permits are granted. Current plans are for production to commence late in 2006.

In early 2005, Matilda Minerals Ltd announced reserves of 2.05 Mt at 6.01% 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, Andranangoo and Lethbridge on the north coast of Melville Island and Puwanapi on the west coast of Bathurst Island. The company reported that feasibility studies indicate that the project could produce 35 000 t of concentrate per year for at least three years containing 13 000 tpa zircon, 9 000 tpa rutile/leucoxene and 11 000 tpa ilmenite. Matilda Minerals Ltd reported that it has an offtake agreement with Astron Limited to take all production from the project and concentrate would be shipped direct to China.

Nickel

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

Resources

EDR decreased marginally (1%) in 2004 from 22.8 Mt to 22.6 Mt. This was partly due to some companies reclassifying lateritic nickel resources to inferred category JORC, pending more detailed resource definition. Of this amount, just over 40% of EDR was in sulphide ores, and the remaining associated with laterites.

Western Australia remains the largest holder of nickel resources with 90% of total EDR. Nickel production continued at the operating sulphide mines of WMC Resources Ltd's Leinster and Mt Keith; LionOre Mining International Ltd's Black Swan and Emily Ann; Jubilee Mines NL's Cosmos; Mincor Resources NL's Mt Elbert, Wannaway, and production commenced at Redross in September 2004 and at Mariners in the first quarter of 2005. Production also commenced from Sally Malay Mining Ltd's Sally Malay mine in August 2004. Sulphide nickel production continued or commenced at another eight mostly small mines. Mining of lateritic nickel continued from Minara Resources NL's Murrin Murrin mine and from the OMC's Cawse mine. Despite ongoing production from the sulphide nickel mines, EDR for sulphide nickel increased marginally from 9.4 Mt to 9.7 Mt in 2004 whereas lateritic nickel decreased from 13.5 Mt to 12.9 Mt.

New South Wales is the second largest holder of EDR with 6.9%, followed by Queensland 2.7%, Tasmania 0.2% and Northern Territory at 0.1%. Nickel resources in both New South Wales and Queensland are associated with laterite deposits, whereas EDR in Tasmania and Northern Territory are mostly sulphides.

Subeconomic demonstrated resources, which account for about 8.9% of total identified resources, increased by 0.2 Mt during the review period. Paramarginal resources increased by 0.5 Mt while submarginal resources decreased by 0.3 Mt in 2004. Western Australia has 80% of submarginal resources.

Inferred resources increased by 3.1 Mt (19%) to 19.5 Mt in 2004. Western Australia maintained its dominant share of inferred resources at just under 90% followed by Queensland with 7%.

The ratio of inferred resources to EDR increased from 0.7:1 in 2003 to 0.9:1 in 2004.

Accessible EDR

Currently, all nickel EDR is accessible for mining. At the rate of production in 2004, AEDR of nickel (including both sulphide and laterite) are sufficient for an average of over 120 years.

JORC Reserves

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

Total JORC Code reserves of nickel are adequate for an average of 37 years at current rates of production.

Exploration

Expenditure on nickel-cobalt exploration during 2004, as reported by ABS, amounted to \$118.2 million, an increase of 68% over the previous period. Western Australia attracted most of this expenditure with \$104.4 million. Nickel exploration continued to target komatiite-hosted nickel sulphide and lateritic nickel deposits in the Yilgarn Craton (WA) and the mafic-ultramafic Giles Complex in Western Australia and South Australia. The East Kimberley region in northern Western Australia also attracted interest. Some of the exploration results of interest in 2004 include:

- WMC Resources Ltd & Falcon Minerals Ltd's drilling at the Collurabbie project, 170 km northeast of the Mt Keith nickel mine (WA), indicated potential for a new nickel province. Drill intersections from the Olympia prospect include 5.77 m at 3.00% Ni, 1.96% Cu and 5.29 g/t PGMs from 279.43 m and 8 m at 1.23% Ni, 1.62% Cu and 3.84 g/t PGMs from 64 m. The Collurabbie project covers over 500 km² of the northern extension of the Gerry Well Greenstone Belt. The mineralisation style and metal association at Collurabbie is regarded as unique in Western Australia. Diamond drilling intersected disseminated sulphide mineralisation over 7 km of strike in the first of two parallel mineralised horizons. The Olympia Prospect occurs within the second mineralised horizon.
- WMC Resources Ltd reporting that the Babel Ni-Cu-Co-PGM deposit in the West Musgrave region, discovered by WMC in 2000, has been drilled by 125 holes that indicate an inventory of mineralisation in the order of one million tonnes of nickel and one million tonnes of copper (with PGM and cobalt credits). A mineral resource had not been defined at the time of the announcement and further metallurgical studies are planned to evaluate the economics of the project. Drilling programs are planned for early 2005 to test for deep mineralisation at Babel and to target a significant electro-magnetic anomaly in the region.

- Drilling by Thundelarra Exploration Ltd and Sally Malay Mining Ltd at the Copernicus North prospect in East Kimberley intersected a broad zone of mineralisation that included intersections grading 1.36% Ni, 0.87% Cu and 0.05% Co over 17 m from 199 m; and 1.45% Ni, 1.16% Cu and 0.05% Co over 14 m from 260 m.
- Western Areas NL reported an intersection of 44.2 m at 3.74% Ni at the T1 deposit being developed at Flying Fox and another intersection of 34 m at 4.4% Ni was announced in February 2005 for the deeper T5 deposit.
- Exploration drilling by Jubilee Mines NL in 2004 included intersections of 4.6 m at 9.2% Ni at Prospero and 5.85 m at 7.93% Ni at the Alec Mairs deposit. These results were followed by very substantial intersections at the Prospero deposit and included 30.5 m at 7.6% Ni in 2005.
- LionOre Mining International Ltd reported that drilling a new and a previously untested geological setting confirmed the presence of a shallowly dipping pyroxenite hosted Ni-Cu-Pt-Pd-Au-Co mineralisation at Billy Ray prospect in the Lake Johnston project. Intersections included 43 m at 0.61% Ni, 0.31% Cu, 0.38 g/t Pt-Pd from 2 m; and 29 m at 0.49% Ni, 0.15% Cu, from 79 m including 2 m at 3.13% Ni, 1.21% Cu, 0.62% Co and 0.56 g/t Pt-Pd from 79 m.
- LionOre also reported intersections from a newly discovered prospect, The Horn, 8km west of Thunderbox; 9.95 m at 0.98% Ni and 0.21% Cu from 133.05 m, including 1.55 m at 2.34% Ni and 0.37% Cu from 133.05 m; and 9.85 m at 0.79% Ni and 0.24% Cu from 110.15 m including 0.30 m at 2.03% Ni and 0.17% Cu from 110.15 m.
- In a joint venture with Pioneer Nickel Ltd, Jubilee Mines NL completed a 2 900 m reverse circulation drilling program at the Acra Joint Venture Project, which returned 40 m at 0.57% Ni and 242 ppm Cu. Further drilling was commenced in 2005.
- At Anomaly 11, 20 km south of the Blair Nickel Mine, an 18 RC hole drilling program by Australian Mines Limited confirmed previous nickel intersections and included 2 m at 2.25% Ni within 10 m at 1.25% Ni.
- Titan Resources Ltd reported intersections of 5 m at 2.11% Ni and 6 m at 3.29% Ni obtained from a drilling program to confirm nickel mineralisation from previous drilling on the mafic-ultramafic contact below open pit at Munda.
- In early 2004, Barra Resources Ltd reported an intersection of 42 m at 1.12% Ni and 0.059% Co from 10 m depth in the saprolite zone of weathered ultramafic rocks (Martins Zone) at the Riverina project, 130 km north of Coolgardie (WA). The oxide nickel saprolite zone has a possible strike length of 1 km. Follow up drilling to test the basal footwall contact of the ultramafic sequence intersected 4 m at 0.7% Ni from 144 m at the footwall of fresh ultramafic rocks. Further drilling of down hole electromagnetic anomalies in the first half of 2005 led to the discoveries of massive and disseminated nickel sulphides at the Riverina Joint Venture project area including 31 m at 1.17% Ni, 618 ppm Cu and 105 ppb Pl, and 1.14 m at 2.28% Ni and 315 ppm Cu.
- At Barrow Creek (NT), Mithril Resources Ltd (in a joint venture of BHP Billiton, Goldstake Exploration Inc and Imperial Granite and Minerals Pty Ltd) reported nickel, copper and silver mineralisation over a strike length of 800 m with the better intersections of 0.35 m at 8.27% Cu, 1.22% Ni and 26.2 g/t Ag at a depth of 110 m; and 0.6 m at 2.27% Cu, 2.86% Ni, and 8.5 g/t Ag at a depth of 170 m. BHP Billiton withdrew from the joint venture in early 2005 and Mithril entered into an option and Joint Venture agreement with Falconbridge (Australia) Pty Ltd to explore and develop nickel sulphide deposits within the Barrow Creek Project. Drilling is to commence in May 2005.
- GME Resources Ltd announced in March 2005 upgraded resources from their infill drilling of their Mt Kilkenny and Eucalyptus lateritic deposits amounting to 18.55 Mt of indicated resources at 1.27% Ni and 0.1% Co, and 22.31 Mt of inferred resource at 1.23% Ni and 0.1% Co at a cut off grade of 1% Ni. High grade intercepts from the infill drilling included 16 m at 1.575% Ni and 0.142% Co at Mt Kilkenny; 11 m at 1.92% Ni and 0.111% Co at Eucalyptus Central; and 7 m at 1.751% Ni and 0.131% Co at Camelback.

- Rox Resources Ltd announced drilling results from lateritic nickel intersections north of Heron Resources Ltd lateritic Highway deposit. Best intersections included 14 m at 0.91% Ni and 0.17% Co and 15 m at 0.76% Ni and 0.45% Co.

Production

Nickel production decreased in 2004 by 2.6% to 187 kt, as reported by ABARE, all from Western Australia. Production of intermediate nickel products (matte and speiss) totalled 106 000 t in 2004 and refined nickel was 122 000 t. The value of all nickel products exported was \$3.3 billion. Australia was the world's second-largest producer, accounting for 13.4% of estimated world nickel output.

During 2004, total nickel-in-concentrates production by WMC Resources Ltd from Leinster, Mt Keith and third party mines at Kambalda eased by under 2% from 117 722 t to 115 774 t, largely due to planned changes in open pit mining at Mt Keith that were partly offset by record performances at the Leinster operations. WMC Resources Ltd is the third largest nickel-in-concentrate producer and accounted for 16% of global nickel-in-concentrate production. Nickel-in-matte production in 2004 from the Kalgoorlie smelter by WMC Resources Ltd also eased by 1.4% from 99 152 in 2003 to 97 780 t in 2004. Production of nickel metal from the Kwinana refinery increased by 1.7% from 61 418 t in 2003 to 62 479 t in 2004. This increase was achieved despite a statutory maintenance shutdown in March 2004 that was followed by a record output of 17 817 t in the fourth quarter to match the recently expanded annual production capacity rate of 70 000 t at the Kwinana refinery.



Nickel briquettes at the Kwinana nickel refinery, Western Australia (WMC Resources Ltd).

World Ranking

Based on figures published by the USGS and modified to incorporate the Australian resources reported here, world EDR of nickel decreased by 1.6% to 61.8 Mt in 2004 (62.8 Mt in 2003). Australia's share of world EDR was 36.6% in 2004 (up 0.3% from 2003), and it remained the largest holder of EDR followed by Russia (10.7%), Cuba (9.1%) and Canada (7.8%).

Russia was again the largest producer with 315 kt (22.9%), followed by Australia with 187 kt (13.6%) and Canada with 180 kt (13.1%). The fourth largest producer was Indonesia with 144 kt (10.5%) and New Caledonia with an output of 122 kt (8.9%).

Industry Developments

ABARE reported that in the first five months of 2005, world nickel prices averaged US\$15 835 a tonne, 14% higher than the average for 2004. ABARE forecasted that for 2005 as a whole, limited growth in production is expected to be offset by continued strong increases in demand by China's stainless steel sector and that together with historically low and diminishing nickel stocks, high nickel prices are likely to be sustained.

Australia has several nickel sulphide mines currently in operation including WMC Resources Ltd's Leinster and Mount Keith, LionOre Mining International Ltd's Black Swan and Emily Ann, Jubilee Mines NL's Cosmos and Mincor Resources NL's Miitel and Wannaway. Production commenced at



Sally Malay open cut nickel mine, Western Australia (Sally Malay Mining Ltd).

Redross in September 2004 and at Mariners in the first quarter of 2005, the Independence Gold NL's Long-Victor, and from Consolidated Minerals Ltd's Beta Hunt operation. Production also commenced from Sally Malay Mining Ltd's Sally Malay mine in August 2004 and the company, in a joint venture with Donegal Resources, commenced initial mining at the Lanfrachi mine. Sulphide nickel mining also continued from another four small nickel mines and WMC Resources Ltd's concentrator at Kambalda processes ores from third party operators.

Two laterite nickel mines were in operation: OM Group's Cawse and Minara Resources NL's Murrin Murrin. All of these operating nickel mines are in Western Australia where there is a nickel smelter at Kalgoorlie and a refinery at Kwinana. Another refinery is located at Yabulu, Queensland.

WMC Resources Ltd commenced ore production from the new 11 Mile Well open pit in late 2004, and production of some 8 000 t of nickel per annum from the recently-acquired Cliffs project, near Mt Keith, is scheduled to start in 2007.

WMC Resources Ltd commenced planning for a new milling and concentrator circuit at Mt Keith, which will be combined with the application of a low-pressure-leach plant to treat existing and future stockpiles of talc and low grade ores from Mt Keith and Yakabindie. Nickel production is expected to increase by 25 000 t per annum from 2008-2009.

Pre-feasibility work also continues at the Yakabindie nickel deposit, 26 km south of Mt Keith, with metallurgical testing under way. WMC Resources Ltd is planning to start production around the end of the decade to replace expected declining production from Kambalda.

In 2005, WMC Resources Ltd was the subject of a successful takeover by BHP Billiton.

In early 2004, BHP Billiton approved the Ravensthorpe Nickel Project in Western Australia and the Yabulu Extension Project in Queensland. Development cost for the mine site at Ravensthorpe is estimated at US\$1.05 billion (~A\$1.38 billion) and US\$350 million (~A\$460 million) for the expansion of the refinery. The Ravensthorpe project includes the development of an open cut mine, treatment

plant and associated infrastructure and is based on three laterite nickel deposits with a combined proved and probable reserves of 236 Mt at 0.67% Ni and 0.03% Co. The company plans annual production of up to 220 000 t of mixed nickel-cobalt hydroxide intermediate product at Ravensthorpe containing up to 50 000 t of nickel and 1 400 t of cobalt, to be shipped from Esperance to Townsville, in Queensland, for refining at the QNI Yabulu refinery. The metal refining section of the refinery is being expanded to increase production to 76 000 t of nickel and 3 500 t cobalt. Engineering, procurement activities and site works were on schedule at both sites and production is planned to start in the second quarter of 2007.

In late 2004 LionOre Mining International Limited made a successful takeover offer for MPI Mines Ltd that resulted in MPI becoming a fully owned subsidiary of LionOre. The takeover resulted in LionOre having 80% control over the Black Swan and the Honeymoon nickel sulphide deposits. In May 2004 ore production commenced from the disseminated nickel sulphide in the Black Swan open pit to supplement mill feed from the Silver Swan underground operations being fed to the Black Swan concentrator. During 2004 the concentrator processed 183 229 t of ore at 5.5% Ni from the underground massive nickel sulphides and 113 617 t at 0.82% Ni from the open pit disseminated ore. Feasibility studies are nearing completion into the viability of upgrading the Black Swan plant from its present throughput of 600 000 t per annum to 1–2 Mt to optimise the open pit operation.

In the Lake Johnstone Operations, LionOre continued development of the Maggie Hays deposit and an upgrade of the nearby Emily Ann processing plant to 500 000 t per annum was completed during late 2004. A feasibility study is currently in progress to evaluate the viability of mining the large disseminated nickel sulphide along with the smaller high grade massive sulphides at Maggie Hays and a decision on development alternatives is expected in the third quarter of 2005.

Prior to its takeover by LionOre Mining International Ltd, MPI Mines Ltd reported that a pre-feasibility study indicated that a proposed 250 000 tpa underground operation at **Wedgetail** (part of Honeymoon Well Project) is viable. An indicated and inferred resource of 1.07 Mt at 6.9% Ni was defined.

LionOre Mining International Ltd announced that a feasibility study was commenced by its subsidiary, MPI Mines Ltd, in 2005 to consider the exploitation of the Honeymoon Well Project resource. The study is planned to be completed by the first quarter of 2006.

In April 2004 LionOre purchased the Bulong lateritic nickel processing plant near Kalgoorlie and commenced a feasibility study into converting the plant into a nickel sulphide hydrometallurgical facility, utilising its proprietary Activox process, to produce 20 000–40 000 t nickel metal per annum. LionOre owns 80% of the Activox process and plans to complete the study in 2005.

Production from Jubilee Mines NL Cosmos Deep ore body in 2004 amounted to 12 297 t Ni. By early 2005 an exploration decline was completed from the Cosmos Deep mine for 350 m to the Alec Mairs deposit, about 550 m below surface. Access to the deposit will be developed following results of an underground drilling program from the decline. An initial resource estimate was announced for Anomaly 1 of 36 Mt at 0.74% Ni at a cut off grade of 0.45% Ni. This deposit is 350 m south of the Cosmos Mine and may be amenable to open cut development. A zone of nickel mineralisation was also being delineated about 500 m below the surface at the Prospero prospect (Anomaly 3), about 4.5 km south of the Cosmos mine. By mid 2005 the company announced an inferred resource of 960 000 t at 5.4% Ni.

Western Areas NL completed a feasibility study for its Flying Fox T1 deposit and development work commenced in late 2004 to access the deposit at about 400 m depth. In mid 2005 the company announced an updated probable ore reserve for its T1 deposit containing about 15 000 t Ni. Ore production from T1 is expected to commence in the June Quarter of 2006. The mine development will be extended to the deeper T4 and T5 deposits provided that sufficient reserves can be established. The company is planning to complete feasibility studies in 2005 for the Diggers South and New Morning/Daybreak deposits. A feasibility study is also being conducted for a proposal to build a nickel concentration plant at Cosmic Boy, half way between Flying Fox and Diggers South.

Sally Malay Mining Ltd commenced operation of the nickel processing plant in August 2004 with the first shipment of nickel concentrates sent from the Port of Wyndham to Jinchuan, China in September 2004. Total production of contained metal in concentrates for 2004 amounted to 2 697 t Ni, 1,468 t Cu, and 159 t Co. Sally Malay Mining Ltd entered in a joint venture with Donegal Resources, the Lanfranchi Joint Venture (Sally Malay 75%, Donegal Resources 25%) to acquire the Lanfranchi Mine by way of a sublease from WMC Resources Ltd for \$26 M. The purchase was executed in late 2004. Total reserves and resources for the Lanfranchi group of deposits amount to 3.65 Mt at 2.02% Ni with a contained nickel content of 73 873 t. Limited mining of the Lanfranchi orebody had commenced at the end of 2004.

Fox Resources Limited commenced production at the Radio Hill nickel mine in July 2004 and the first shipment of nickel and copper concentrates to China was sent from Dampier in August 2004. Total production for 2004 of contained metal in concentrates was 926 t Ni, 612 t Cu and 49 t Co. Continuing underground drilling at Radio Hill intersected 37 m grading 0.65% Ni, 0.84% Cu, and 0.03% Co. The company also commenced a bankable feasibility study into heap leaching disseminated nickel and copper resources at Radio Hill and the Sholl deposits that amount to an inferred resource of 7.03 Mt containing 39 000 t Ni, 53 000 t Cu and 2 800 t Co. Fox Resources Ltd announced that it had acquired 100% ownership in the Sholl nickel deposits. In March 2005 the company also announced that it had acquired the Ruth Well nickel deposit about 12 km north of the Radio Hill treatment plant. Following drilling programs, intersections of high grade mineralisation included one with 11 m at 4.3% Ni, 1.5% Cu and 0.13% Co from 55 m.

Australian Mines Ltd commenced mining nickel ore at the Blair Nickel Mine with the first ore despatched for toll treatment at the Kambalda Nickel Concentrator in March 2004. A total of 10 920 t of ore was mined at an average grade of 2.81% Ni for 277 t of contained nickel metal. Other areas being explored by the company in the vicinity of the Blair Nickel Mine include Anomaly 11, Duplex Hill, Blair South, Marshall and Anomaly 20.

Mincor Resources NL operated three nickel mines in 2004 south of Kambalda (WA) comprising the Miitel, Wannaway and the Redross Mine, which commenced operations in the September quarter of 2004. The combined metal in concentrate production for the three mines in 2004 was 8436 t Ni, 167 t Co and 828 t Cu. A fourth mine, the Mariners, commenced operations in the first quarter of 2005 and the mining of the North Miitel deposit also commenced in March 2005. Mincor continued to explore for extensions from the existing orebodies. Encouraging intersections included 5.37 m at 3.1% Ni from 745 m with a true width of about 4.1 m at South Miitel and 7.14 m at 3.2% Ni with a true width of 4.0 m intersected below Wannaway. Intersections announced during the first half of 2005 included 4.8 m at 5.67% Ni north and down plunge of North Miitel at a down-hole depth of 628.7 m and a true width of about 3 m; and 1.7 m at 2.87% Ni, down plunge to the south below the Redross deposit at a down-hole depth of 550.5 m.

During 2004, Independence Group NL continued to mine its Long deposit and conducted development and associated mining operations of its Victor South and Gibb South orebodies. Total production for 2004 amounted to 8 083 t Ni and 575 t Cu. A significant proportion of this production was sourced from outside the defined ore zones. The company continued drilling for extensions of the existing resources and significant extensions included 26.45 m at 6.8% Ni at Victor South. A decision was also made to commence a 1 315 m long exploration decline from the southern end of the Long ore body at a cost of \$4 million. The decline will test possible extensions of the ore at Long South where previous drill intercepts include 3.6 m at 3.3% Ni.

Development work at the Avebury Project (Viking and Avebury North deposits) in Tasmania, owned by Allegiance Mining NL, included the completion of a 1 200 m long decline in mid-January 2005. By the end of the first quarter in 2005, 7 611 m of drilling from the surface and the decline had extended the Avebury mineralisation by 370 m and the zone remains open to east and west. One intersection 150 m west of the resource boundary consisted of 12 m grading at 1.6% Ni. Another intersection of 12 m in North Avebury graded 4.3% Ni with 2 m of massive nickel mineralisation at 14.1%. The company expects to complete the resource drilling required for a bankable feasibility

study by May 2005. On 30 June 2005 the company reported that a Development Application and an Environmental Management Plan had been approved by the West Coast Council of Tasmania. The Definitive Feasibility Study is on schedule for completion by September/October 2005.

In their prospectus of September 2004, Metallica Minerals Ltd announced plans to explore and develop the NORNICO project that comprises several drilled Ni-Co laterite deposits (including Bell Creek) and is prospective for additional nickel laterite deposits and sulphide Ni-Cu-PGE deposits. The NORNICO project is located 250 km northwest of BHP Billiton's Yabulu nickel refinery near Townsville, North Queensland. The laterite deposits contain an inferred resource of 2.42 Mt at 1.4% Ni and 0.1% Co at a cut-off grade of 1% Ni and an additional low grade inferred resource of 3.87 Mt at 0.78% Ni and 0.1% Co with a cut-off grade of 0.6% Ni. Over the next two years, Metallica plans to complete infill resource drilling, metallurgical studies, a scoping study and a pre-feasibility study on the mining and treatment of initially the Bell Creek resource using atmospheric leach processing to produce a Ni-Co concentrate for sale to the Yabulu nickel refinery or other refineries. In late 2004 Metallica signed a heads of agreement covering the key terms for a joint venture with BHP Billiton over the northern half of the NORNICO project area in search for nickel sulphide deposits. In January 2005, Metallica also acquired 100% ownership of the Dingo Dam lateritic nickel deposit, about 50 km south east of the NORNICO project area.

During 2004, production from Reliance Mining Ltd's Beta Hunt operation amounted to 3 847 t Ni. Following the successful takeover of Reliance Mining Ltd during the first half of 2005, Consolidated Minerals Ltd committed to spend \$10 million to the end of 2005 to escalate exploration of East Alpha project, which is adjacent to the producing Beta Hunt mine. The program includes development of an 800 m exploration drive from the Beta Hunt mine to access the top levels of the East Alpha mineralised zone.

View Resources Ltd commenced nickel production from its Carnilya Hill mine in December 2003 followed by further production in August 2004 from its Zone 29 orebody. Total production from both mines in 2004 amounted to 872 t Ni. In early 2005, the company announced extensions to the Carnilya Hill deposit with significant intersections including 8.69 m at 2.84% Ni and 5.17m at 2.19% Ni. Extensions to the Zone 29 deposit included a significant intersection of 5 m at 3.54% Ni.

Sherlock Bay Nickel Corporation Limited conducted feasibility studies on their Discovery nickel deposit at Sherlock Bay. The studies aim to evaluate treatment of low grade disseminated nickel sulphide ore from open pit mining via bacterial assisted heap leaching to produce leach liquor from which the contained copper, nickel and cobalt values would be precipitated. The precipitation process was designed to produce a copper cement product and a nickel/cobalt hydroxide concentrate. A review of the feasibility study, initiated by the company in 2005, concluded that further metallurgical test work is required. Intersections from the latest drilling in the first half of 2005 included 25 m at 0.82% Ni commencing 210 m from surface and 44 m at 0.53% Ni commencing 454 m from surface.

Heron Resources Ltd embarked on a pre-feasibility study for the development of a 50 000 t/a mine and hydrometallurgical processing plant Goongarrie, about 80 km north of Kalgoorlie. The project is based on the company's laterite nickel resources of 903 Mt grading at 0.74% Ni and 0.05% Co comprising a northern siliceous component of 546 Mt in the Goongarrie-Siberia region and an eastern saprolite component of 357 Mt in the Bulong-Kalpini region 20 to 70 km east and north east of Kalgoorlie. The siliceous component of the resource is considered by the company to be amenable to beneficiation by screening to a leach feed grade of 1.5% Ni. In early 2005, Heron Resources signed a letter of intent to enter into a joint venture with Inco Limited to develop the Kalgoorlie Nickel Project. The pre-feasibility study continues to focus on resource definition and metallurgy, specifically the screen upgrade characteristics of the siliceous mineralisation. The initial 800 x 80 m metallurgical sample drilling and batch-scale metallurgical beneficiation test work was completed in the first quarter of 2005. Significant recent drill results include 50 m at 1.5% Ni.

The annual production for 2004 from the Murrin Murrin lateritic nickel plant operated by Minara Resources Limited amounted to 28 518 t of nickel and 1 975 t of cobalt. A record production of 8 163 t nickel and 579 t cobalt was reported for the first quarter of 2005. Minara also entered into agreement with WMC Resources Ltd to process nickel oxide overburden material from the WMR Leinster mining operation. The arrangement was made to enhance the nickel feed grade at the Murrin Murrin Plant.

Niobium

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 by-product of tantalum mining at the Greenbushes mine (WA).

Resources

Niobium EDR remained unchanged at 194 kt in 2004. Most EDR of niobium is in the Greenbushes pegmatite deposit with minor resources in New South Wales.

Exploration

Data relating to exploration for niobium are not available.

Production

A total of 240 t of niobium in export tantalum products was produced from the Greenbushes deposit in Western Australian.

World Ranking

World EDR is estimated at 4.4 Mt of which Brazil has 4.3 Mt. Australia has the second largest EDR with 0.2 Mt followed by Canada with 0.1 Mt.

World production in 2004 from USGS data is 32 800 t Nb of which 29 000 t came from Brazil. Canada produced an estimated 3 300 t.

Industry Developments

No major developments were reported in 2004.

Phosphate

Phosphate rock is the major resource mined to produce phosphate fertilisers, which are needed for cropping, pasture and horticulture production. Phosphorous is also used in animal feed supplements, food preservatives, anti-corrosion agents, cosmetics, fungicides, ceramics, water treatment and metallurgy. The characteristic minerals in phosphate rock are members of the apatite group ($\text{Ca}_5(\text{PO}_4, \pm \text{CO}_3, \pm \text{OH})_3(\text{OH}, \text{F}, \text{Cl})$).

Australia's commercial resources of phosphate are in Queensland (Phosphate Hill, 135 km SSE of Mt Isa) and on the Indian Ocean Territory of Christmas Island. Phosphate Hill is a world-class rock phosphate resource that is close to surface and easy to access and mine. The rock is ideal for the manufacture of high analysis fertilisers for domestic and international use. The first di-ammonium phosphate (DAP) fertiliser utilising Phosphate Hill ore was produced in late 1999.

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

DAP and MAP have different ratios of phosphorous and nitrogen, and have slightly different applications. Both products are generally produced as granules with a diameter of between 2–4 mm.

DAP (20% P and 18% N) is used on broad-acre crops such as cereal, legume, fodder, horticultural and row crops, and dairy and newly-established pastures. MAP (22% P and 10% N) assists with early crop growth and enhances phosphorous uptake in broad-acre crops.

Resources

EDR of phosphate rock decreased by 5% in 2004 compared to the previous year. All EDR is sedimentary phosphate rock (phosphorites), with an average grade of about 24% P_2O_5 at Phosphate Hill. The decrease resulted from production depletion and exclusion of small zones at the peripheries of the Phosphate Hill deposit, which are no longer regarded as practical to mine. There is no publicly available information on Christmas Island's phosphate resources. Geoscience Australia, however, has reasonably detailed knowledge of this deposit and known resources remaining within the existing mining lease on the island.

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

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

Exploration

Data relating to exploration for phosphate are not available.

Production

Australia produced 2 039 kt of fertiliser in 2004 (649 kt DAP and 1 390 kt MAP). DAP came from rock phosphate ore treated at **WMC Resources' Queensland Fertiliser Operations** (QFO) at Phosphate Hill. MAP was manufactured from domestic (Phosphate Hill) and imported rock phosphate.

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

WMC Fertilisers' QFO is the only Australian producer of DAP and MAP, both of which are sold in Australia and overseas. Its major production-based operations – phosphate mine and beneficiation, phosphoric acid, ammonia and granulation plants – are at Phosphate Hill. Supporting facilities are located at Mt 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 2004, **WMC Fertilisers** sold 75% of its fertiliser in Australia and 25% in Asia and produce a new product, sulphur-fortified MAP, which is expected to capture greater marketing opportunities in the future. Sulphur-fortified MAP provides a high-quality, low cadmium and low-heavy-metal alternative for pastures and cropping requiring sulphur.

Shale Oil

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

Resources

Until recently, all 10 of the central Queensland oil shale deposits were held by Southern Pacific Petroleum (SPP), either solely or with joint venture partners. The last systematic review of the in situ mineralisation for these ten oil shale deposits was completed by SPP in 2000 to comply with the JORC Code.

Australia has 4.6 GL (29 million barrels) of shale oil EDR. This could increase significantly if the research and development demonstration-scale processing of shale oil conducted at the Stuart deposit near Gladstone from 2000 to 2004 were to lead to a commercial plant. Paramarginal and submarginal demonstrated resources are 202.1 GL (1.3 billion barrels) and 3719 GL (23.4 billion barrels) respectively. The demonstration plant at Stuart produced over 1.5 million barrels of oil. The shale tonnage processed was small in comparison to the overall resource, so there is no change in the year 2000 reserves estimate at the reported level of precision.

Production

Oil production at the Stuart demonstration plant in 2004 was down 33% to 67 ML (421 000 barrels) as final plant trials were successfully completed. These tests achieved stable production runs at or above 100% of design capacity solid feed rates and oil yield, while maintaining product quality and adhering to EPA emissions limits.

The oil products from the demonstration plant were Ultra Low Sulphur Naphtha (ULSN) 55–60% and Light Fuel Oil (LFO) 40–45%. The ULSN, which can be used to make petrol, diesel and jet fuel has a sulphur content of less than 1 ppm. To put this into perspective, petrol in Australia previously contained about 500 ppm sulphur. Regulatory guidelines are in place to reduce this to 150 ppm for petrol and to 50 ppm for diesel.

World Ranking

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

Industry Developments

In early 2004, SPP's oil shale assets were acquired by Queensland Energy Resources Ltd (QERL) and later in the year QERL announced the successful completion of the Stuart Stage 1 demonstration facility. QERL is now focusing on conducting extensive research and design studies for the next phase of its Queensland oil shale operations based on the lessons learned from the demonstration plant.

QERL stated that the results to date from Stage 1 have demonstrated that large scale oil extraction from the Stuart deposit can be done. The company also added that over past years, the testing has shown that there are many potential alternatives and variations to the details of the Stage 1 design, which need to be fully explored if the value of these resources is to be maximised for all stakeholders. The facility is now on care-and-maintenance in an operable condition to allow for any further testing if required while design efforts continue on the next phase of development. It is estimated that these studies will take 12–18 months, after which a decision to proceed with front-end engineering design of the preferred project configuration will be made.

Tantalum

Demand for tantalum has increased steadily since 2002. Australia, through the operations of Sons of Gwalia Ltd, is the world's largest producer of tantalum in the form of tantalum concentrates. The company also controls the world's largest stock of tantalum resources, principally in its holdings at Greenbushes and Wodgina (WA).

Resources

EDR increased by 30% to 52 090 t in 2004 due to a reclassification of the Brockman rare earth resource in Western Australia. EDR at Greenbushes and Wodgina marginally increased and decreased respectively. Subeconomic resources decreased due to a reclassification of resources. Reclassification the Brockman resource reduced inferred resources by 11% on 2003 estimates.

Exploration

Data relating to exploration for tantalum are not available.

Production

Production data for the Greenbushes and Wodgina mines were not released for the full calendar year. Haddington International Resources produced 216 065 lbs (98 t) of Ta₂O₅ at its Bald Hill deposit.

World Resources and Production

Based on world estimates published by the USGS and modified by Geoscience Australia to take account of recent discoveries, Australia has close to 95% of the world's EDR of tantalum. Canada has the second largest resource base.

World production in 2003, based on USGS estimates modified to account for later Australian data amounted to 1 110 t Ta. Production was dominated by Australia, with 640 t in 2004 (about 57% of world output), a partial figure for the year. Other producers of tantalum metal during the period include Brazil (200 t), Canada (55 t), Ethiopia (35 t) and Congo (20 t).

Industry Developments

Sons of Gwalia went into receivership in 2004. Operations are continuing on a limited basis under an administrator at both the Greenbushes and Wodgina mines.

Tin

Tin is used in solders for joining metals and pipes, as a coating for steel cans, and also 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 automobile industry, and in cans for various uses. Another major use for tin is the manufacture of tinplate (steel sheet coated with tin), which accounts for about 27% of world tin consumption. Tinplate is used for containers (cans) of food products, drinks, and also for oils, paints, disinfectants and chemicals.

Resources

EDR at December 2004 was 163 kt tin, 12% higher than the previous year. This resulted from increases in ore reserves and mineral resources at the Renison Bell and Mount Bischoff deposits in Tasmania. Total EDR of tin comes from four deposits – Renison Bell, Mount Bischoff, Greenbushes (WA), and Collingwood (North Qld).

Accessible EDR

All tin EDR are unencumbered and there are no restrictions on mining these deposits.

JORC Reserves

EDR is the sum of JORC Code reserve categories plus measured and indicated resources, which Geoscience Australia considers will be economic over the long term. In 2004, JORC reserves of tin accounted for approximately 40% of AEDR.

Exploration

Exploration for alluvial tin in New South Wales and Tasmania increased during the year in response to increased prices. Marlborough Resources continued exploration over deep lead alluvial deposits at the Tingha prospect (8 km south of Inverell, NSW), Emmaville prospect (50 km north east of Inverell), and the Kiawarra prospect (35 km northeast of Yass, NSW).

Malachite Resources completed an exploration drilling program at the Sheep Station Hill prospect (20 km east of Inverell) and the Newstead prospect (4 km southeast of Sheep Station Hill). Drilling at Sheep Station Hill intersected mineralisation averaging 0.2% Sn within a series of greisen veins hosted by granite. Exploration commenced at the Mt Ramsay prospect, western Tasmania, where Malachite Resources is testing airborne electromagnetic anomalies within the Crimson Creek Formation, which hosts the Renison Bell mine (23 km south of Mt Ramsay).

Production

Australia's mine production in 2004 was 800 t tin in concentrates (79% less than in 2003) and 467 t of refined tin ingots (22% less than 2003). Total tin exports for 2004 were 218 t valued at \$1.05 million.

Mine production of tin in Australia has been declining with the closure of mines in Queensland, New South Wales and Tasmania since the mid-1980s. At the start of 2003, Australia had three operating tin mines – Renison Bell underground mine (Tas), Ardlethan alluvial mine (NSW) and Greenbushes open cut mine (WA). Production at Renison Bell was suspended in May 2003. Prior to this, the mine had been a major producer for almost 40 years and was one of the world's largest underground tin mining operations. During 2004, only two small mines were in production at Ardlethan and Greenbushes. Ardlethan alluvial operations closed in August 2004, and at year's end the only tin production was from Greenbushes. While there has been a strong resurgence in tin prices (on the London Metal Exchange) during 2003 and 2004, Australia's production has declined as mines close and resources remain at low levels.

World Ranking

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

Industry Developments

Following more than a decade of low prices, world tin markets showed signs of recovery in 2003 in response to reductions in tin stocks and decreases in mine production. Prices rose to US\$5300/tonne at the end of 2003 ahead of an increase to more than US\$9 000/tonne by December 2004. In response, several companies initiated proposals to re-open old mines or restart development of projects previously suspended because of low prices.

Bluestone Tin Ltd continued work on four tin projects, which are at various stages of development. These projects are:

Renison Bell (15 km northeast of Zeehan, Tasmania): Bluestone purchased the mine and concentrating plant in March 2004 and progressively refurbished both. Mining and processing re-commenced in February 2005 and by late March the concentrator had processed 62 605 t ore to produce concentrates with 164.9 t contained tin.

Exploration drilling was carried out from underground to test for extensions of the Deep Federal mineralised fault structure. High grade mineralisation was intersected to the north of the area of known resources and this resulted in a significant increase in resources.

Rentails Project: Bluestone investigated the feasibility of extracting tin from old mine tailings, which accumulated during the past 40 years of mining at Renison Bell. Fuming or roasting/smeltering techniques are being investigated to recover the tin. Drilling and bulk sampling of the tailings dam were completed and identified mineral resources were estimated to be 17.9 Mt averaging 0.42% Sn.

Mount Bischoff: In January 2005, Bluestone purchased the historical Mount Bischoff mine located 80 km north of the Renison Bell mine. Total measured + indicated + inferred resources were estimated by former owners to be 742 000 t averaging 1.23% Sn (9 127 t contained tin metal). Bluestone plans to re-establish the open cut mine and ore will be trucked to the Renison mill for processing.

Collingwood Project (30 km south of Cooktown, North Queensland): The former owners completed a considerable amount of underground development and site infrastructure prior to cessation of development in the late 1980s because of low market prices (refer Australia's Identified Mineral Resources 2004 for details). During 2004, Bluestone continued refurbishing the main decline and underground mine workings and purchased new equipment for the mine. Mine production is anticipated to commence in the latter part of 2005.

At **Ardlethan**, alluvial mining operations progressed northwards towards the abandoned Wild Cherry open cut. However, the nature of the alluvial resources changed near the open cut and performance of the operation was hampered by increased clay-content in the alluvials and a decrease in mine grades. Production for the six months ended 30 June 2004 was 378 512 kg tin, which was 37% less than for the previous six months. The recovered grade for the six months to 30 June 2004 was 1.28 kg tin/bank cubic metre (kg/BCM) compared to 1.93 kg/BCM for the previous six months. During the last few years, the recovery rate for the operation was 45% of the total contained tin in reserves. Mining operations ceased in August 2004 as the operation became unprofitable.

Greenbushes mine produced 467 tonnes refined tin ingots in 2004. Greenbushes is the world's largest hard rock tantalum mine. Tin occurs in association with tantalum minerals and is recovered as a by-product during ore processing. It is produced in ingot form from a smelter at the site.

Van Dieman Mines purchased 13 exploration and retention licences over a number of deep lead alluvial deposits in northeast Tasmania. The licence areas are in a belt extending from the Blue Tier granite in the south through to the northeast coast of Tasmania and extend off-shore into Ringarooma Bay. Historical records up to 1980 show that in excess of 39 000 t tin has been recovered from this region most of it from alluvial operations. During the 1960s and 1970s a number of major companies conducted exploration and evaluation drilling programs, which delineated significant resources of alluvial tin in the Scotia, Central Ringarooma, Great Northern Plains and Offshore deposits. Van Dieman Mines has applied for mining leases over these deposits and proposes to commence mining at Scotia, Endurance and Central Ringarooma.

Uranium

Uranium has two major peaceful uses: as the fuel in nuclear power reactors to generate electricity; and in the manufacture of radioisotopes for medical applications. Approximately 16% of the world's electricity is currently generated by the use of uranium in nuclear reactors. Some 439 nuclear power reactors are operating in 31 countries; a further 69 new reactors are under construction or planned for completion within the next ten years. Much of this growth will occur in China, India, Japan and South Korea. A total of 16 countries generate more than 25% of their total electricity requirements from nuclear reactors. Australia has no significant national demand for uranium and all mine production is exported under nuclear safeguards agreements with importing countries.

Resources

Geoscience Australia prepares estimates of Australia's uranium resources within categories defined by the OECD Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA). The estimates in each category are for 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 3.

TABLE 3. Correlation of resource classification schemes for uranium.

National Scheme	NEA/IAEA Scheme	Tonnes U recoverable
Economic Demonstrated Resources	Reasonably Assured Resources (RAR) recoverable at less than US\$40/ kg U	701 000
Paramarginal Demonstrated Resources	RAR recoverable at US\$40–80/ kg U	13 000
Submarginal Demonstrated Resources	RAR recoverable at US\$80–130/ kg U	33 000
Economic Inferred Resources	Inferred Resources (IR) recoverable at less than US\$40/ kg U	343 000
Subeconomic Inferred Resources	IR recoverable at US\$40–130/ kg U	53 000

Australia's EDR were estimated to be 701 000 t U, an increase of 26 000 t U compared to the previous year, resulting from increases in reserves and resources at Olympic Dam. These increases at Olympic Dam were due to combined effects of: i) on-going underground development drilling, and ii) reserve/resource estimates at December 2004, the company using a higher long-term price of \$30/lb U₃O₈ compared with \$23.33/lb for the previous year.

Australia had an additional 343 000 t U in Inferred Resources recoverable at costs of <US\$40/kg U – by far the world's largest resources in this category. The majority of these resources are in the south-eastern part of the Olympic Dam deposit, where exploration drilling from surface is currently defining large tonnages of additional resources.

Almost all of Australia's EDR are within the following six deposits:

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

Olympic Dam is the world's largest deposit of low cost uranium. Based on ore reserves and mineral resources reported by WMC Resources as at December 2004, Geoscience Australia estimates that the deposit contains 499 400 t U in RAR recoverable at <US\$40/kg U. This represents almost 30% of the world's total resources in this category.

Accessible EDR

Just over 10% of uranium EDR is inaccessible for mining. Western Australian Government policies prohibit uranium mining for nuclear purposes from any mining leases granted after June 2002, hence uranium deposits in that State are classified as inaccessible resources. Inaccessible resources also include those deposits in the Alligator Rivers region, where mining leases are too small to accommodate the proposed mine and treatment plant facilities, including water retention ponds. These lease areas cannot be increased in size as they are surrounded by the Kakadu National Park.

JORC Reserves

EDR is the sum of JORC Code reserve categories plus those resources in measured and indicated categories, which Geoscience Australia considers will be economic over the long term. In 2004, JORC of 447 000 t U accounted for just over 70% of AEDR.

World Ranking

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

Exploration

Expenditure on uranium exploration in Australia declined over two decades leading up to 2003. From early 2003, market prices for uranium have increased with spot market prices more than doubling from US\$10/lb U_3O_8 (early 2003) to US\$26.25/lb U_3O_8 in May 2005. This has seen a resurgence of exploration activity marked by a number of new uranium-focussed junior exploration companies listing on the Australian Stock Exchange. Uranium exploration expenditure in Australia increased to \$13.96 million in 2004, more than double that for the previous year (\$6.38 million). Currently there are over 20 companies exploring for uranium compared with five actively exploring in 2003.

In 2004, all uranium exploration was in the Northern Territory and South Australia with the main areas and deposit types targeted being:

- Arnhem Land (NT) – exploration for unconformity-related deposits in Palaeoproterozoic metasediments below a thick cover of Kombolgie Sandstone.
- Frome Embayment (SA) – exploration for sandstone uranium deposits.
- Gawler Craton/Stuart Shelf region (SA) – exploration for hematite breccia complex deposits.

WMC Resources continued a major exploration drilling program at **Olympic Dam** where significant additional resources were identified in the south-eastern portion of the deposit. Total resources as at December 2004 were almost 30% higher than in December 2003.

Heathgate Resources announced the discovery of a new zone of uranium mineralisation approximately 3 km south of the Beverley deposit. Referred to as the **Deep South** zone, it was found using a range of geophysical surveys followed up by an extensive drilling program comprising more than 120 holes. The company also reported other discoveries in and around the Beverley mine.

Alliance Resources/Quasar Resources reported that drilling at the **Beverley 4 Mile** prospect (10 km northwest of the Beverley mine) along the western margins of the Frome Embayment intersected uranium mineralisation. Hole AK009 intersected 1.5m at 0.26% eU_3O_8 from 146m depth. Mineralisation is within carbonaceous sands thought to be Late Jurassic in age and equivalent to the Algebuckina Sandstone. If this interpretation is correct, it represents the first known discovery of significant uranium mineralisation within Mesozoic sediments in South Australia. It also highlights the potential for further discoveries in these sediments, which underlie extensive regions of the Frome Embayment.

Southern Cross Resources continued exploration drilling to test Tertiary palaeochannel sands in the southern portion of the Frome Embayment (SA). In 2004, the company discovered a new zone of low-medium grade uranium mineralisation in an area of the Yarramba palaeochannel, approximately 1.5 km north-west of the Honeymoon deposit. The zone (identified as the **Brooks Dam** prospect) has been tested by drilling over 1 km along the palaeochannel. Grades and thicknesses of mineralised intersections were measured using a down-hole Prompt Fission Neutron probe. This gives more reliable uranium grades than the gamma-ray probes normally used for measuring grades of mineralised intersections in this type of sandstone-hosted uranium deposit.

Southern Cross also completed airborne electromagnetic survey and ground gravity surveys over the Billeroo region and defined the extent of the Billeroo palaeochannel. A program of 117 holes was completed to evaluate the resources at the **Goulds Dam** prospect (75 km NW of Honeymoon), which is within the palaeochannel. Updated resource estimates are expected in 2005.

Minotaur Resources continued exploration drilling at the **Prominent Hill** Cu-Au-U deposit, approximately 150 km northwest of Olympic Dam. The geological setting and style of mineralisation are broadly similar to the Olympic Dam deposit, however, the average uranium grades of drill intersections at Prominent Hill are 100 ppm U, much lower than for Olympic Dam, which averages 400–500 ppm U.

Production

Australia's uranium production for 2004 came from its three mines: Ranger open cut (5 138 t U_3O_8), Olympic Dam underground (4370 t U_3O_8) and Beverley in situ leach (1084 t U_3O_8), a record level of total production – 10,592 t U_3O_8 (8982 t U), 19% higher than for 2003. Australia, with approximately

22% of world uranium production in 2004, is the world's second largest producer after Canada (29%). While there are a number of undeveloped deposits in Western Australia, Northern Territory, South Australia and Queensland, only the Northern Territory and South Australia permit uranium mining.

Exports

Exports in 2004 reached a record 9 648 t U₃O₈ (8182 t U) valued at A\$411 million. Exports of Australian uranium are controlled by Australian Government bilateral safeguards agreements, which are designed to ensure that Australia's uranium is used only for electricity generation and is not diverted to any military purposes. Importing countries must be signatories to the International Atomic Energy Agency's safeguards arrangements and have entered into an agreement with the Australian Government to adhere to safeguard obligations for exporting uranium. In addition, the Government recently announced the requirement for countries purchasing Australian uranium to have ratified the Additional Protocol under the Nuclear Non-Proliferation Treaty. This is to strengthen current safeguards arrangements covering exports of uranium.

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

Industry Developments

Uranium market developments: Resurgence in spot market prices for uranium continued in 2004. This stemmed from reductions in secondary supplies of uranium available to world markets together with draw-down of stockpiles. Since 1990, world uranium requirements for electricity generation have exceeded mine production, and in recent years mine production accounted for less than 60% of world requirements. The balance has been met from secondary sources including: stockpiles of natural and low-enriched uranium held by electricity utilities and conversion plants; and down-blending of highly enriched uranium (HEU) from ex-military stockpiles in both the Russian Federation and the USA. Over the last few years, the Russian Federation has retained this material to meet the growing demand for uranium for increasing domestic electricity generation. This has decreased the availability of secondary supplies to world markets

Ranger: Operated by Energy Resources of Australia Ltd (ERA), the mine achieved record production for 2004. Mining of the No. 3 Orebody is expected to continue until at least 2008, after which the pit will be used for the storage of tailings. Production from stockpiled ore will continue until 2012. Metallurgical test work was undertaken to investigate the feasibility of processing lateritic ore, which has been stockpiled from earlier mining operations.

Olympic Dam: Production at Olympic Dam for 2004 was 38% higher than for the previous year. Reconstruction of both the copper and uranium solvent extraction plants (destroyed by a fire in late 2001) was completed and the new uranium solvent extraction plant operated at planned production rates during the year.

WMC Resources has been investigating the feasibility of a major expansion of operations, which would increase annual production to 500 000 t copper, 15 000 t U₃O₈ and 500 000 ounces gold. The study includes:

- A major drilling program (90 drill holes) to better define the resources in the southern part of the deposit;
- Assessing alternative mining, treatment and recovery methods for the southern part of the deposit;
- Identifying and evaluating water and energy supply options; and
- Logistics planning that may include linking Olympic Dam to the national rail network.

Evaluation of mining methods and scale of operations was finalised in March 2005. Open cut mining is the preferred method, where it is proposed to mine 35 Mt/year from the open pit and 5 Mt/year from the existing underground operations. During the period, WMC Resources was the target of takeover bids, firstly by Xstrata and then by BHP Billiton. BHP Billiton, with a bid of \$9.2 billion (US\$6.9 billion), secured control in June 2005 and will continue evaluation of the major expansion at Olympic Dam.

Beverley: In 2004, the Beverley mine produced 920 t U, making it the world's largest single in situ leach uranium mine. Mining progressed from the North orebody to the much larger Central orebody. Installation of the main trunk lines connecting the plant to the Central orebody was completed.

Honeymoon: Southern Cross Resources commissioned an engineering study to determine the cost of a plant at Honeymoon with production capacity of 400 t U₃O₈/year. Based on results, a decision was made to keep the project on hold. A program of drilling was completed to better define the resources at Honeymoon and East Kalkaroo deposits.

Jabiluka: In February 2005, the Mirarr Gundjeihmi Aboriginal people, ERA Ltd and the Northern Land Council signed an agreement for the long-term management of the Jabiluka lease. The agreement obliges ERA Ltd (and its successors) to secure Mirrar consent prior to any future mining development of uranium deposits at Jabiluka. The project site remains on long-term environmental care. The traditional Aboriginal land-owners have refused to grant approval for development of the Jabiluka mine. ERA Ltd has announced that there will be no further development at Jabiluka without the formal support of Aboriginal people, and subject to feasibility studies and market conditions.

Western Australia: In March 2004, the Western Australian Government and WMC Resources reached agreement to terminate the *Uranium (Yeelirrie) Agreement Act 1978*. The Act was legislated in 1978 to facilitate the possible construction of a uranium and vanadium treatment plant at Yeelirrie. The Western Australian Government has prohibited the mining of uranium for nuclear purposes from any mining lease granted after June 2002.



ABOVE: Drums of Beverley's uranium oxide concentrates being loaded into shipping containers ready for export (Heathgate Resources Pty Ltd).

LEFT: Beverley's uranium extraction plant and main trunklines (pipelines), which carry solutions from the wellfield to the plant (Heathgate Resources Pty Ltd).

BELOW: Wellfield at Beverley in situ leach uranium mine, South Australia (Heathgate Resources Pty Ltd).



Vanadium

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

While there are a number of vanadium deposits in Australia, Windimurra (75 km southeast of Mount Magnet, WA), has been the only mining operation in recent years.

Resources

Australia currently has no EDR of vanadium. Following closure of the Windimurra mine and processing plant (refer 'Industry Developments' below) the large resources for this deposit have been reclassified as paramarginal resources.

Significant tonnages of vanadium are classified at subeconomic paramarginal and submarginal resources within deposits in the Yilgarn (Windimurra, Gabanintha) and Pilbara regions (Balla Balla, Don Well) of Western Australia.

Exploration

There was virtually no exploration for vanadium during the year.

Production

Vanadium-bearing ore was not mined in Australia during 2004. Most of the world's mine vanadium production during the period was from South Africa (45%), China (30%), and Russia (23%).

Industry Developments

Mining at **Windimurra** ceased in late 2003 and the mine closed in May 2004. Processing plant and equipment were removed from the site during the latter part of the year. Xstrata AG reported that the operations were uneconomic in recent years at prevailing prices of US\$1.70–1.80 per pound V_2O_5 . Prices for V_2O_5 were less than US\$1.50 per pound throughout the period 2000 to 2002 and US\$1.70–\$1.80 during 2003. Prices have steadily increased since to more than US\$8.70 per pound V_2O_5 by the end of 2004.

An inquiry into the closure of Windimurra was conducted by the Government of Western Australia. It found that the mine's three-year period of operation was hampered by a number of challenges, including a downturn in world vanadium prices, an increase in the value of the Australian dollar, and difficulties in recoveries of magnetite in the processing plant. Recommendations from the inquiry included a need for the Government to protect its interests in light of decisions made by multi-national companies relating to mining projects.

During 2004, metallurgical test work was carried out on the Barrambie and Gabanintha vanadium prospects in Western Australia. At the **Barrambie** Ti-V-Fe project (65 km NW of Sandstone), Reed Resources Ltd completed test work on ore to evaluate metallurgical processes for producing titanium slag, pig iron and vanadium. Work focussed on optimising production of ilmenite concentrates suitable for upgrading to titanium slag or synthetic rutile.

At the **Gabanintha** V-Ti project (40 km SE of Meekatharra WA), Greater Pacific Gold investigated the metallurgy and technology required to extract vanadium and titanium. The company also drilled large-diameter-cored holes to acquire sample material for further metallurgical test work.

Zinc, Lead, Silver

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

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

The relative scarcity, attractive appearance and malleability of **silver** make it suitable for use in jewellery, ornaments and silverware. Its extensive use in coins throughout history has declined over the last forty years. In Australia, the 1966 fifty-cent piece was the last coin in general use to contain silver (80% silver, 20% copper). Silver is mined and produced mainly as a co-product of copper, lead, zinc, and to a lesser extent, gold. Today, photographic paper and film, followed by the electronics and jewellery/tableware industries are the most important users of silver. Demand for silver as an anti-bacterial agent is likely to double over the next few years as its use increases in water treatment (as an ioniser with copper in domestic swimming pools) and for biocide and bacteriostatic activity in plastic and textiles formulations. Silver based biocides are also being tested as a replacement for arsenic based preservatives in wood treatment.

Resources

Australia's total resources of zinc, lead and silver increased in 2004. Total identified resources of zinc increased by almost 10 Mt to 89.3 Mt of contained zinc; lead from 55.2 Mt to 56.8 Mt of contained lead; and silver from 107.3 kt to 109 kt of contained silver.

ZINC

EDR of zinc at 41 Mt is the world's largest holding, accounting for over 18% of world's total. Queensland remained pre-eminent, its EDR increasing from 20.5 Mt to 26.6 Mt (65% of EDR). The rise in EDR was affected predominantly by reclassification of resources and improved grades at Mt Isa and George Fisher (including the Hilton orebody), while resources in other deposits were unchanged. The Northern Territory at 9.4 Mt again had the second largest EDR and its share of the total category was 23% compared to 29% in 2003. New South Wales had the third largest EDR with 2.7 Mt (2.8 Mt in 2003). The decrease was primarily due to depletion of resources through production. Western Australia's EDR increased to just under 1.5 Mt, (1 Mt in 2003), mainly through reclassification of resources at the Jaguar deposit. Victoria remained unchanged at 0.39 Mt. Tasmania's EDR increased to 0.43 Mt (0.29 Mt in 2003).

Of Australia's EDR of zinc, over 50% is in JORC ore reserve categories, compared to almost 65% in 2003. The ratio of EDR to production is just over 30 and ore reserves to production close to 16.

Paramarginal demonstrated resources of zinc increased from 6.3 Mt to 8.5 Mt due to reclassification of the Mt Isa and George Fisher resources. Submarginal demonstrated resources fell slightly from 16 Mt to 15 Mt over the year. These variations are attributed to relatively small changes in most states and the Northern Territory.

Total inferred zinc resources decreased by 20% to 25.2 Mt in 2004 following the reclassification of resources, particularly Mt Isa and George Fisher.

LEAD

Lead EDR of 23 Mt is about 40% of total lead resources and over 30% of world EDR, making Australia the leading inventory country. Queensland has over 60% of EDR, mainly at Cannington and Mt Isa, with other holdings in the Northern Territory, New South Wales, Western Australia and Tasmania.

Total identified resources increased from 55.2 Mt in 2003 to 56.8 Mt in 2004. EDR increased by 18% to 22.9 Mt of contained lead, which comprised 40% of total identified resources. Queensland retained first ranking with EDR increasing from 10.2 Mt to 14.1 Mt, over 60% of total EDR. The increase was due to additional resource definition and reclassification at Mt Isa. The Northern Territory decreased slightly from 5.53 Mt to 5.25 Mt EDR, 23% of the total. New South Wales declined further from 1.7 Mt in 2003 to 1.6 Mt in 2004, through production at Broken Hill and Elura. EDR in Western Australia static at 1.8 Mt, while in Tasmania it rose by 0.02 Mt (22%) to 0.11 Mt due to a small increase in resources at Rosebery.

Of Australia's EDR of lead, 43% is in JORC ore reserves categories (down from 54% in 2003). The national EDR/production ratio is 35 and ore reserves/production ratio 15.

Paramarginal demonstrated resources of lead are 2.9 Mt (2 Mt in 2003), which is 5.1% of total identified resources. Submarginal demonstrated resources totalled 9.3 Mt (9.2 in 2003) or just over 16% of total identified resources. These changes are attributed to relatively small adjustments in most states and the Northern Territory in both categories.

Total inferred lead resources fell by over 13% to 21.6 Mt following reclassifications of resources, in particular the Mt Isa and George Fisher resources.

SILVER

EDR for silver are 50 000 t, which is 18% of world EDR. Queensland has 78% of EDR mainly in the Mt Isa, Cannington, Century and Hilton deposits. Other holdings are in the Northern Territory, South Australia, New South Wales and Western Australia.

EDR decreased marginally to 41.4 kt in 2004. Queensland remained the major holder, although its EDR went from 32.2 to 30.1 kt (less than 73%) as a result of resource depletion at Cannington. The Northern Territory at 4.5 kt had the second largest EDR and its share of the total was marginally down to 11%. South Australia had the third largest EDR with 2.5 kt (2.4 kt in 2003) followed by New South Wales at 2.3 kt (2.2 kt in 2003), with minor increases at Broken Hill and Elura offsetting decreases at Tritton. Western Australia was next with 1.2 kt (0.8 in 2003), followed by Tasmania with 0.41 Mt (0.31 kt in 2003), due to minor increases at Rosebery, with Victoria unchanged at 0.28 kt.

Of Australia's EDR of silver, 63% is in JORC ore reserve categories. EDR/production ratio is 19 and ore reserves/production 12.

Paramarginal demonstrated resources of silver increased from 9.82 kt in 2003 to 17.6 kt in 2004 and submarginal demonstrated resources increased from 11.8 kt to 16.9 kt over the year. These changes result from increases at Mt Isa and George Fisher mines and Bowdens deposit in New South Wales. Total inferred silver resources decrease slightly to 41.4 kt in 2004 following an increase of resources at Mt Isa's open pit mine.

Exploration

In 2004, expenditure on zinc-lead-silver exploration was \$33.4 million, 12% higher than in 2003, and about 16% of total base metal expenditure of \$207.3 million. In the March quarter 2005 spending on zinc-lead-silver exploration was \$7.0 million, slightly higher than the preceding March quarter.

Production

Mine production of zinc, lead and silver was 1.34 Mt, 700 000 t and 2 237 t respectively during the period. This reflected a slight decrease for zinc (1 000 t), no change for lead and a slight increase for silver (367 t) compared to 2003. As a producer, Australia ranks first for lead, third for zinc after China and Peru and fourth for silver after Mexico, Peru and China. Cannington is the world's largest and lowest cost silver and lead operation and produced almost 272 kt of lead and 41.7 Mozs of silver in 2004. Century had the largest zinc output at 517 kt.

World Ranking

Australia has the world's largest EDR of zinc (18%), lead (26%) and second largest EDR of silver (15%) behind Poland (18%). In terms of production, it ranks second for lead, third for zinc after China and Peru, and fourth for silver after Mexico, Peru and China.

Industry Developments

Encouraging exploration results reported during the period under review include the following.

Triako Resources' announcement that the Main Lens of its Hera project (NSW) is estimated to contain an inferred resource of 1.49 million tonnes @ 9.4g/t gold, 0.5% copper, 4.4% lead, 4.3% zinc and 24g/t silver.

Kagara Zinc more than doubled the total inventory of zinc, copper and gold resources at its Mt Garnet project (Qld). Zinc, copper and gold resources increased to 28.4 Mt from the previously reported 11.6 Mt following drilling campaigns at the Mungana and Balcooma deposits, both of which are key future production centres for the Mt Garnet operations.

In the Northern Territory a new estimate for oxide and sulphide ore at Compass Resources' **Browns** project south of Darwin increased contained lead by 29% and copper by 17%. Measured, indicated and inferred resource at Browns now total 40 Mt @ 0.5% Cu, 4.52% Pb, 0.11% Co, 0.09% Ni and 13g/t silver.

TasGold Ltd's drilling in south-west Tasmania yielded high-grade base and precious metal intersection at Wart Hill. A 7 m mineralised zone returned 7.8% Zn, 4.4% Pb, 78g/t Ag and 0.4g/t Au, in semi-massive to massive sulphides 35m vertically below surface.

Terramin Australia completed 32 cored holes at its Angas zinc project, southeast of Adelaide (SA). As a result resources have increased to 2.8 Mt (indicated and inferred) @ 14% Zn equivalent and include an indicated resource of 1.1 Mt @ 13% Zn, 5% Pb and 50g/t Ag. Energy services company **Sempre Energy** has taken a strategic stake in Terramin Australia's proposed 400 000 tpa Angas lead-zinc project in South Australia.

Oxiana Ltd entered into an agreement to acquire from 1 July 2005 the Golden Grove base metal operation (WA) from Newmont Mining Corporation at a cost of \$265 million.

Ivernia Inc entered into an agreement with Sentient Global Resources Fund to acquire its 49% interest in the **Magellan** lead mine (WA) for C\$100 million. On completion of the transaction, Ivernia will have 100% ownership of the Magellan mine's 2.2 billion pounds of in situ lead reserves. Ivernia forecasts 2006 production of about 220 million pounds of lead in concentrate. Mining from the Cano pit at Magellan and commissioning of the lead processing plant commenced in January 2005.

Exploration of the **Menninnie Dam** zinc lead and silver deposit (SA) is the subject of an agreement between Zinifex Australia Limited and Terramin Australia Limited, who hold exploration title over the deposit. Under the agreement, Zinifex may earn up to a 70% interest in the project by spending up to \$8 million in a number of stages.

PRODUCTION AND RESOURCE LIFE



Uranium extraction plant using ion exchange technology at Beverley mine, South Australia
(Heathgate Resources Pty Ltd).

Production and Resource Life

Australia's production of selected mineral resources, concentrates and metals for 2004 are presented in Table 4. Australian Bureau of Agricultural and Resource Economics (ABARE) reported that mineral commodities for which mine production rose significantly in 2004 compared with 2003 were manganese ores and concentrates (up 33%), uranium (18%), iron ore and pellets (11%), lead ores and concentrates (10%), copper ores and concentrates (6%), and black coal (5%). Australia's major mineral commodities that recorded production decreases in 2004 include diamonds (down 34%), refined lead and bullion (15%), refined zinc (14%), iron and steel (12%) and gold (9%).

ABARE reported that Australia's export earnings from mineral resources rose to \$58.3 billion in 2004, an increase of \$5.7 billion or 11% compared with 2003. This stronger performance mainly reflected higher prices for many of the major minerals exported (eg coal, iron ore, nickel, copper), largely as a result of increased demand from China.

To sustain these export earnings and maintain Australia's position as one of the world's leading minerals producers, resources need to be discovered and developed for production at rates sufficient to meet demand. To facilitate assessment of the future supply capability of identified resources, ratios of AEDR to current mine production have been provided in the commodity reviews above, as an indicator of the resource life. This indicator can change quite rapidly, for example with significant changes in production rates and metal prices. Iron ore provides an example of how resource life can vary markedly over a short period, with increasing production in response to growing demand from Asia being a major factor contributing to the life of iron ore resources halving from 125 years in 1995 to around 60 years in 2004.

AEDR of other bulk mineral commodities can sustain current rates of mine production on average for the following approximate periods: black coal 100 years, bauxite 80 years, manganese ore 20 years and brown coal 450 years. Ratios of AEDR to current mine production for other minerals give approximate resource lives (years) of 70 for sulphide nickel, 380 for laterite nickel, 50 for copper, 95 for ilmenite, 90 for rutile and 50 for zircon.

Resource life duration for gold (about 22 years at current rates of production), lead (less than 30 years) and zinc (less than 25 years) are amongst the lowest. Gold price increases over many years have contributed to increasing expenditure on gold exploration since 1980. Despite the fact that there has been a progressive increase in Australia's EDR of gold since the mid-1980s, there is still a need for ongoing successful gold exploration in the short and medium terms to discover sufficient resources to maintain this commodity as one of Australia's main exports.

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

TABLE 4. Australian production and exports of selected mineral products 2004.

Commodity	Production	Exports	Export value \$ million
Aluminium			
Bauxite (Mt)	56.6		126
Alumina (Mt)	16.7	13.6	4 092
Aluminium (Mt)	1.9	1.5	3 615
Coal			
Black raw (Mt)	375		
Black saleable (Mt)	295	224	13 379
Brown raw (Mt)	68		
Copper			
Ores and concentrates (kt)	2 532	1 185	1 380
Refined primary (kt)	490	322	1 202
Diamond (Mc)	21	23	456
Gold			
Mine production (t)	259		
Refined (t) ^(a)	371	312	5 551
Iron and Steel			
Ore and Pellets (Mt)	234	210	6 167
Iron and steel (Mt)	8.4	2.9	2 122
Lead			
Ores and concentrates (kt)	981	406	444
Refined (kt)	232	211	250
Bullion (kt)	140	151	214
Manganese			
Ores and concentrates (Mt)	3.4	2.8	398
Mineral sands			
Ilmenite concentrates (kt)	1934	756	76
Rutile concentrates (kt)	162	147	98
Synthetic rutile (kt)	720	487	270
Titanium dioxide pigment (kt)	202	178	424
Zircon concentrates (kt)	441	420	276
Nickel			
Concentrate (kt Ni)	187		
Refined (kt)	228 ^(b)	206	3 323 ^(c)
Uranium (kt U ₃ O ₈)	10.6	9.7	411
Zinc			
Ores and concentrates (kt)	2 497	1 884	751
Refined (kt)	473	325	475

Notes for Table 4

Source: Australian Mineral Statistics, ABARE, December quarter 2004

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

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

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

(c) Sum of all nickel product export values.

EXPLORATION



Exploration drilling south of the Beverley mine, South Australia (Heathgate Resources Pty Ltd).

Expenditure

Mineral exploration expenditure for a range of commodities is collected quarterly by ABS. The following discussion is based on the survey data for 2003–04 (year ended 30 June 2004) and calendar year 2004. Differentiation of exploration spending into commodity groups prior to 1980 is based largely on a breakdown of ABS totals by Geoscience Australia.

Financial Year 2003–04

Australian mineral exploration spending in 2003–04 rose by 7.4% to \$786.7 million, which was the highest financial year current dollar spending since 1998–99. In constant 2003–04 dollars spending was also at its highest since 1998–99 (Figures 2 & 3).

FIGURE 2. Australian mineral exploration expenditures by commodity in constant 2003–04 dollars (Based on ABS data deflated by Consumer Price Index series).

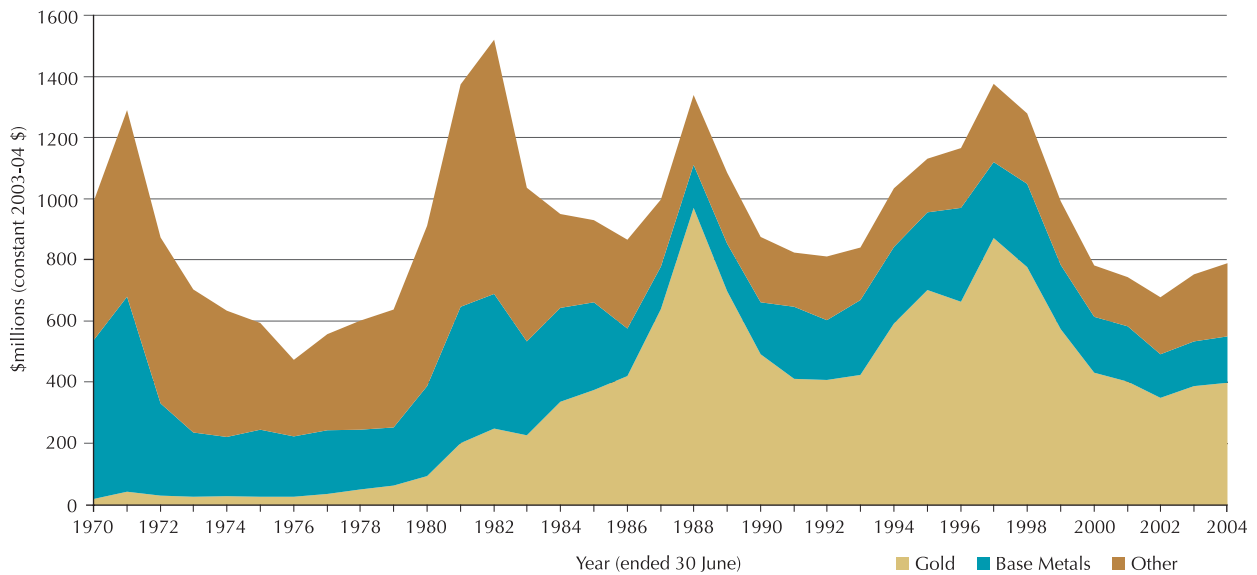
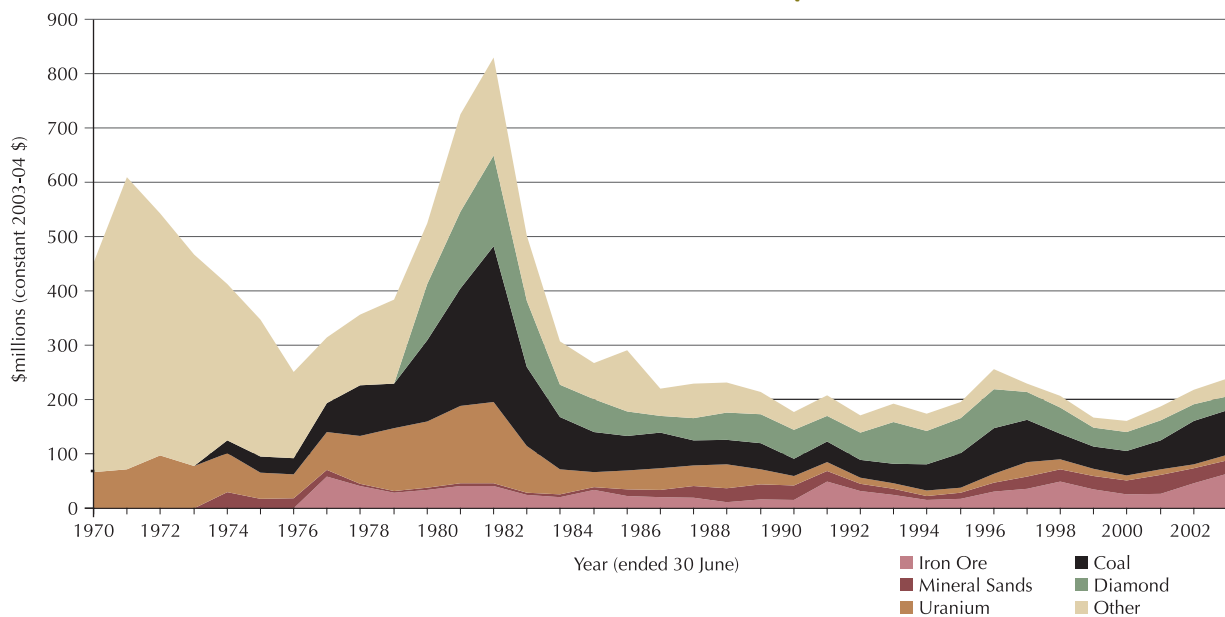


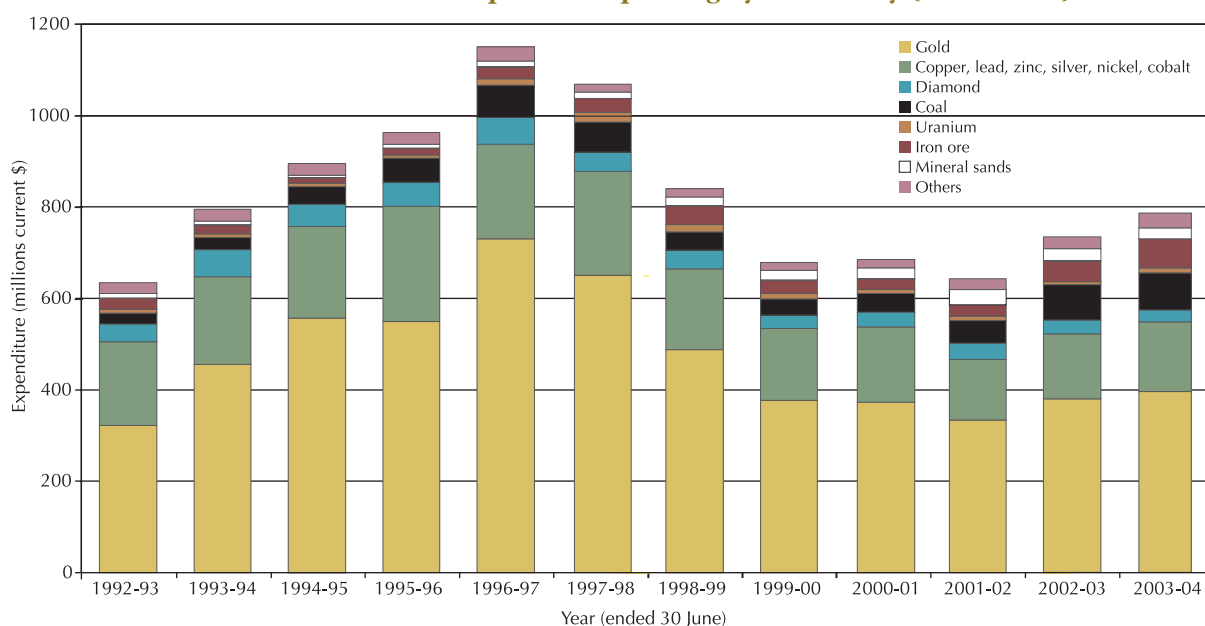
FIGURE 3. Australian mineral exploration expenditures, excluding gold and base metals, in constant 2003–04 dollars (Based on ABS data deflated by Consumer Price Index series).



Gold dominated exploration spending (50.5%) and, at \$397.1 million, was at its highest level since 1998–99 (Figure 4). Iron ore, nickel and uranium recorded strong growth with increases of 43.5% (to \$63.7 million), 27.8% (to \$84.2 million) and 52.2% (to \$10.5 million) respectively. Copper exploration fell by 4.8% to \$37.8 million and zinc-lead-silver exploration fell by 18.9% to \$29.7 million. Mineral sands exploration spending fell again in 2003–04 to \$23.8 million, a fall of 12.8%.

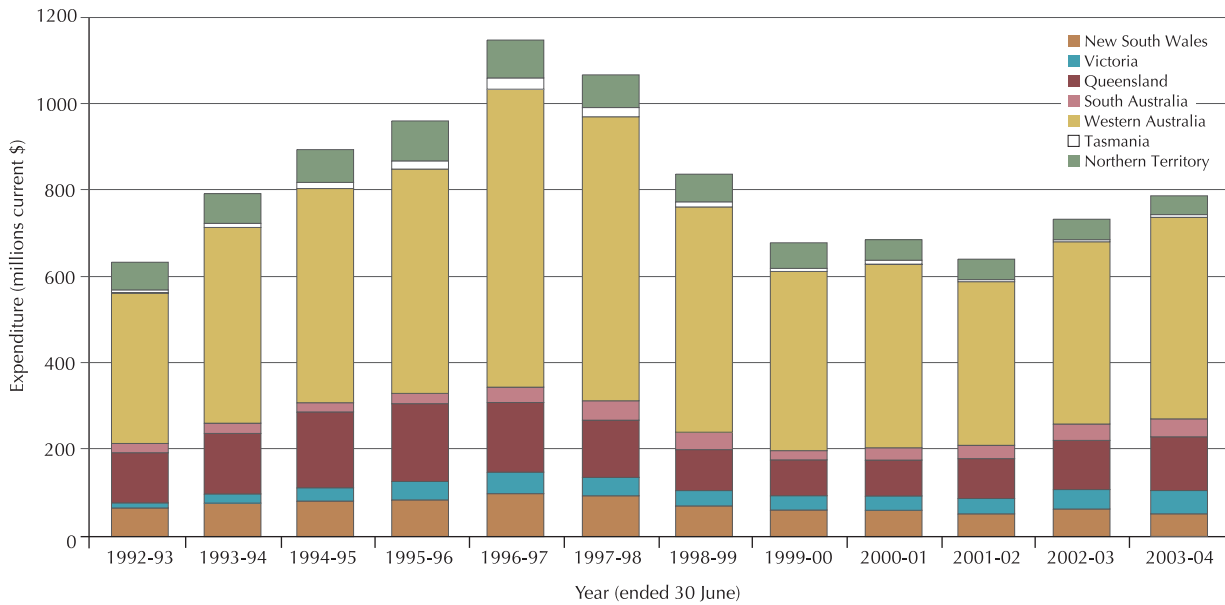
Although in constant 2003–04 dollars gold remained the dominant commodity sought, the level of spending grew only slightly and was less than in 2000–01 and less than half the 1996–97 level and less than half the 1987–88 peak (Figure 2). Similarly, base metals showed only a small increase and was less than a quarter of the 1970–71 high. Spending on iron ore exploration was the highest recorded for the period for which data is available. In contrast, diamond exploration was at its lowest level for the period for which data is available.

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



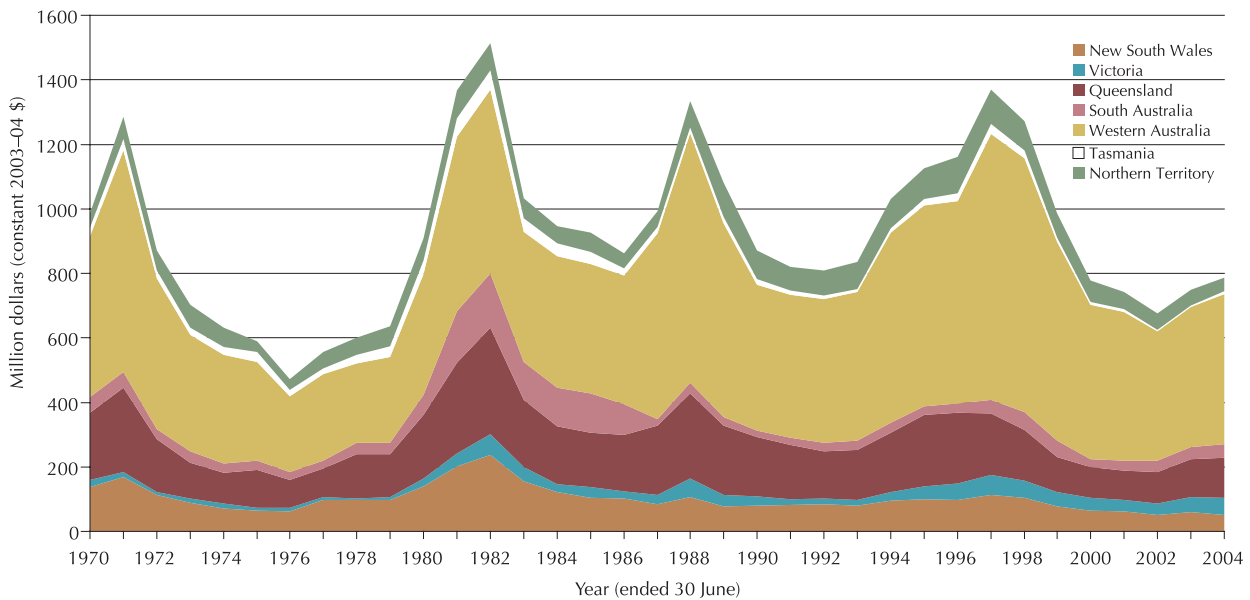
All States except New South Wales and the Northern Territory recorded increases in mineral exploration activity. Western Australia dominated with \$465.8 million, 59.2% of total Australian mineral exploration expenditure in 2003–04 (Figure 5). Queensland with \$125.2 million, an increase of \$11.2 million, was the second largest State with 15.9% of the national total. A spending increase of 16% resulted in Victoria surpassing New South Wales as the third State with a total of \$53.5 million. Expenditure in New South Wales fell by 14% to \$50.5 million and in the Northern Territory it fell by 13.5% to \$42.4 million. At \$41.7 million (up 13.6%), South Australian spending was at its highest level since 1998–99. Tasmania recorded a massive 76.7% rise in exploration to reach \$7.6 million.

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



In constant 2003–04 dollar terms, Western Australia, Queensland, Victoria, South Australia and Tasmania had exploration spending that was at its highest level for a number of years (Figure 6). However, New South Wales was at the lowest level since before 1970 and the Northern Territory was at its lowest since 1976–77.

FIGURE 6. Australian mineral exploration expenditures by State in constant 2003–04 dollars (Based on ABS data deflated by Consumer Price Index series).



Calendar Year 2004

On a calendar year basis, spending in 2004 rose by 24% to \$920.6 million. This strong growth in the calendar year compared to the 2003–04 financial year is attributed to the substantial increases in spending in the second half of the year. Spending was \$511.9 million in the second half of 2004 compared to \$384.6 million in the equivalent period in 2003. This growth reflects strong growth in price for many commodities on the back of anticipated strong and growing demand, particularly from China.

While gold remained the predominant target in calendar year 2004 its share of total spending fell below 50%. Although gold received \$414 million in the year, an increase of \$40.3 million its share of total spending fell to 45% (Table 5). The base metal group increased its share of total spending to 22.5% – \$207.4 million, an increase of \$72.7 million.

TABLE 5. Australian mineral exploration spending by commodity 2003 and 2004 (Source ABS).

Commodity	Exploration Spending (\$ million)		Change (\$ million)	Proportion of Australian Total Exploration Spending		Change % points
	2003	2004		2003	2004	
Gold	373.7	414.0	40.3	50.4	45.0	-5.4
Copper	34.5	55.8	21.3	4.7	6.1	1.4
Zinc, lead, silver	29.7	33.4	3.7	4.0	3.6	-0.4
Nickel, cobalt	70.5	118.2	47.7	9.5	12.8	3.3
Base Metals	134.7	207.4	72.7	18.2	22.5	4.4
Diamond	27.6	25.4	-2.2	3.7	2.8	-1.0
Coal	84.7	96.9	12.2	11.4	10.5	-0.9
Iron Ore	52.1	97.9	45.8	7.0	10.6	3.6
Mineral Sands	26.3	24.7	-1.6	3.5	2.7	-0.9
Uranium	8.9	14.8	5.9	1.2	1.6	0.4
Others	28.5	38.4	9.9	3.7	3.5	-0.2

This growth is uneven across the base metals with nickel being the major contributor as spending rose by \$47.7 million (68%) to \$118.2 million, 12.8% of total spending. Copper spending rose by \$21.3 million (61%) to \$55.8 million, 6.1% of total spending. In contrast exploration for zinc, lead, silver rose by only \$3.7 million (12%) but its share of national spending fell slightly. Iron ore exploration rose by \$45.8 million to \$97.9 million and its share of total spending increased by nearly 50% to 10.6%.

In contrast to the financial year results, all States/Northern Territory recorded increases in calendar year 2004. Western Australia remained dominant with an increase of \$107 million in 2004 to \$539.9 million which was 58.6% of Australian spending virtually the same share as in 2003 (Table 6). Queensland and South Australia both recorded strong dollar increases in spending but these only increased their share of national spending by around 1 percentage point.

TABLE 6. Australian mineral exploration spending by State 2003 and 2004 (Source: ABS).

State	Exploration Spending (\$ million)		Change (\$ million)	Proportion of Australian Total Exploration Spending		Change % points
	2003	2004		2003	2004	
Western Australia	432.9	539.9	107.0	58.4	58.6	0.3
Queensland	116.4	154.1	37.7	15.7	16.7	1.0
New South Wales	54.9	59.7	4.8	7.4	6.5	-0.9
Northern Territory	41.5	49.7	8.2	5.6	5.4	-0.2
Victoria	50.1	52.4	2.3	6.8	5.7	-1.1
South Australia	35.9	55.5	19.6	4.8	6.0	1.2
Tasmania	4.4	8.2	3.8	0.6	0.9	0.3

Exploration Stage

ABS, for the first time, reported 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 compliant resource estimate of any classification prepared. Subsequent spending on exploring that mineralisation would be classified as further delineation or extension of a deposit.

Nationally 39% of exploration spending was directed at the search for new deposits. Tasmania had the highest proportion of exploration in this category with 54.7% of its expenditure on new deposits, whereas the Northern Territory had the lowest at 31.3%. This share of exploration directed to the search for new deposits is in line with the Metals Economics Group (MEG) world survey of non-ferrous minerals exploration budgets for 2004, which found that 39% of the budget for exploration in Australia was for grassroots exploration.

Exploration Drilling

In 2003–04, ABS reported that exploration drilling totalled 5.68 million metres, an increase of 0.52 million metres (10%) from 2002–03. Of the 2003–04 total, 2.68 million metres (47%) was on the search for new deposits.

Drilling in calendar year 2004 was, at 6.521 million metres, 22% higher than in 2003. This was a sustained growth throughout the year with increases in each quarter compared to equivalent quarters in 2003, although in the March quarter growth was limited to 2.6%.

Exploration Outcomes

The increase in exploration activity saw an increase in the number of reported intersections of mineralisation and several new discoveries. The more significant announcements during the year included:

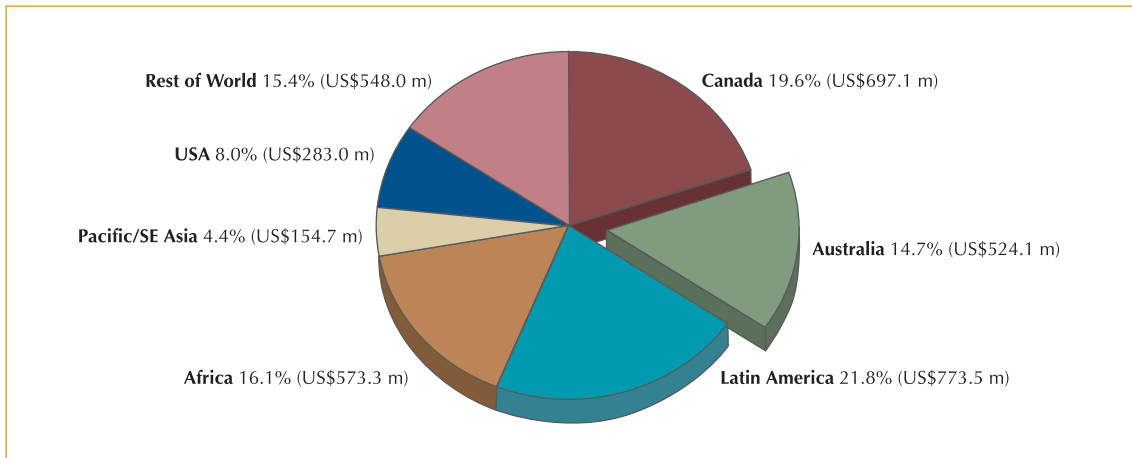
- A major increase in resources at Olympic Dam, South Australia.
- Release of an initial resource estimate for the Prominent Hill deposit in South Australia.
- A first indication of the size of the West Musgrave Ni-Cu-Co-PGE deposits, Western Australia.
- Discovery of the Collurabbie Ni-Cu-PGE prospect in Western Australia.
- Discovery of the Jacinth mineral sands deposit in the Eucla Basin, South Australia.

Details of exploration for individual commodities are reported under the review of resources for each commodity in this review.

World Exploration

The MEG survey of world non-ferrous mineral exploration budgets for 2004 reported an increase of 58% to an estimated total budget of US\$3.8 billion. Budgets of companies responding to the survey amounted to US\$3.55 billion (Figure 5). Of the respondents' budgets, US\$524.1 million (14.7%) was directed to exploration in Australia. While this was the highest budget since 1998, Australia's share of world budgets fell again, to fifth globally, and exploration by major companies has declined as a proportion of total Australian exploration expenditure.

FIGURE 7. Distribution of world non-ferrous mineral exploration budgets, 2004
(Source: Metals Economics Group).



According to the MEG survey, Australian-based companies expended 59% of their 2004 mineral exploration budgets on Australian projects. The survey included 287 companies with non-ferrous exploration budgets of more than US\$100 000 that were exploring in Australia, an increase of 44 over 2003. Budgets for Australian exploration were directed to gold (US\$323.9), base metals (US\$136.4 million) and diamonds (US\$24.6 million).

Short-Term Outlook

The Australian Bureau of Agricultural and Resource Economics (ABARE) predict export earnings from Australia's mineral resources to recover strongly in 2004–05 to \$65.12 billion, an increase of 22.8%. ABARE expects world consumption of all major mineral (and energy) commodities to slow in 2005 and they expect mixed results for prices due to differing supply prospects in the market. Consequently ABARE expect Australian mineral export volumes to increase.

Both world and domestic mineral exploration levels grew strongly in 2004 and mergers and acquisitions of mining companies have been minimal. The higher metal prices, particularly for the base metals, and the sustained higher gold price levels are conducive to greater exploration activity in 2005. Demand from China is expected to continue to influence trends in both prices and exploration, particularly for base metals, iron ore, coal and uranium.

Offshore Mineral Exploration in Commonwealth Waters

The Commonwealth *Offshore Minerals Act 1994* regulates exploration for and mining of minerals, other than petroleum, over the continental shelf three nautical miles beyond the territorial baselines (generally the low water mark) of the States and Territories. Applications for a mineral exploration licence (MEL) are made to the Designated Authority, usually the relevant State or 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 the satisfactory performance of licence conditions. There is a mandatory reduction of 50% of the licence area on renewal of a MEL.

As at May 2005, a total of 70 offshore MEL applications had been received since February 1990. Currently there is one active licence in Ringarooma Bay, Tasmania, where past exploration has identified an inferred tin resource of some 200 million bank cubic metres. **Van Dieman Australia** is currently investigating the viability of mining the onshore and offshore deposits. During 2004 interest returned to exploring for diamonds in the Joseph Bonaparte Gulf in the northwest of Australia. There are now four exploration license applications submitted for approval in the Joseph Bonaparte Gulf, including two from **Bonaparte Diamond Mines**. This exploration is directed at discovering economic deposits of alluvial diamonds in offshore palaeochannels and tidal shoals. To date no diamonds have been discovered in Commonwealth waters, however, gem quality diamonds have been discovered adjacent to the Berkeley and Ord Rivers in State waters.

On 15 November 2004, Australia made a submission to the United Nations Commission of the Limits of the Continental Shelf. The submission contains information on the proposed outer limits of the continental shelf of Australia beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured. Consideration of the submission was included in the provisional agenda of the 15th session of the Commission in April 2005.

Geoscience Australia completed a desktop review of Australia's offshore minerals (McKay et al., 2005) as input to a workshop convened by CSIRO's Wealth from Oceans National Research Flagship and Exploration and Mining Division (Yeats & McConachy, 2005). The review found that the discovery and eventual economic extraction of offshore mineral deposits pose significant technical, political and environmental challenges. Scientific as well as offshore exploration is needed to acquire data and build up geoscientific knowledge on known and new types of offshore mineral deposits, establish their distribution in Australia's offshore regions and evaluate their possible wealth and future use.

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

cpt carats per tonne

C\$ Canadian dollar

CSIRO Commonwealth Scientific and Industrial Research Organisation

EAR-1 estimated additional resources – category 1

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 Identified Mineral Resources and Ore Reserves*

kg kilogram

km kilometre

kt kilotonne (thousand tonnes)

ktpa kilotonne per annum

L litre

lbs pounds

m metre

m³ cubic metre

Mc million carats

MEL mineral exploration licence

ML million litres

Mlbs million pounds

mm millimetre

Moz 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

oz ounces

PDR paramarginal demonstrated resources

PGM platinum-group metals

ppm parts per million

Qld Queensland

RAB rotary air blast

RAR reasonably assured resources

RC reverse circulation

SA South Australia

SDR subeconomic demonstrated resources

t tonne

Tas. Tasmania

tpa tonnes per annum

U uranium

U₃O₈ 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 their use and conservation. Results of resource assessment can be used also to set priorities for mineral exploration and research to indicate mineral potential where alternative land uses are being considered.

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

The principles of the McKelvey system, were retained, as were most of the definitions used by BMR in its original system, although minor changes were made to some. Guidelines on applying the system were established, and adopted. It was decided that the term 'reserves' would not be used for regional or national aggregates of resources, so as to avoid the confusion arising from its use with different meanings in other contexts.

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

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

The modified McKelvey system and JORC Code are compatible, and data reported for individual deposits by mining companies are used by Geoscience Australia in the preparation of its assessments of Australia's mineral resources

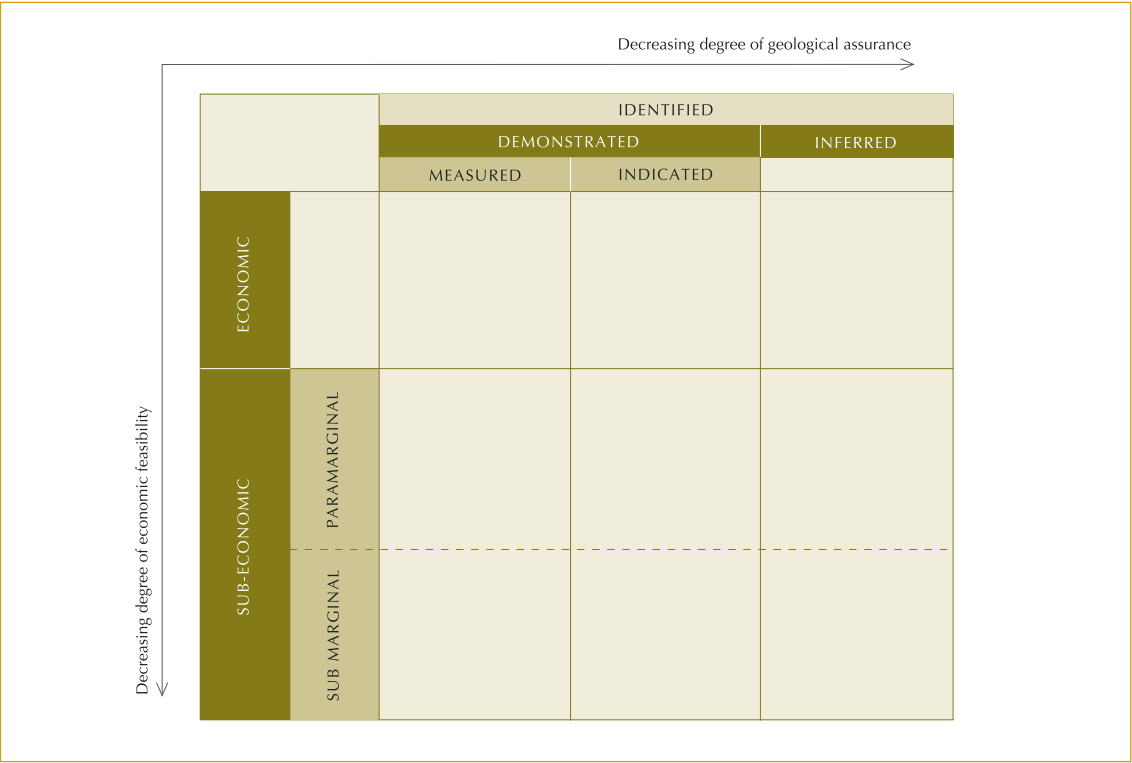
CLASSIFICATION PRINCIPLES

Geoscience Australia classifies known (identified) mineral resources according to two parameters: degree of assurance of occurrence (degree of geological assurance) and degree of economic feasibility of exploitation. The former takes account of information on quantity (tonnage) and chemical composition (grade); the latter takes account of changing economic factors such as commodity prices, operating costs, capital costs, and discount rates.

Resources are classified in accordance with circumstances at the time of classification. Resources which are not available for development at the time of classification because of legal and/or land-use factors are classified without regard to such factors; however, the amount of resource thus affected will, wherever possible, be stated for each classification category.

The classification framework is designed to accommodate all naturally occurring metals, non-metals, and fossil fuels, and to provide a means of comparing data on different resources, which may have a similar end use (eg. petroleum, coal, and uranium as energy sources).

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



TERMINOLOGY AND DEFINITIONS

Resource: A concentration of naturally occurring solid, liquid, or gaseous materials in or on the Earth’s crust and in such form that its economic extraction is presently or potentially (within a 20–25 year timeframe) feasible (see guideline i).

CATEGORIES OF RESOURCES BASED ON DEGREE OF ASSURANCE OF OCCURRENCE

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

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

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

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

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

CATEGORIES OF RESOURCES BASED ON ECONOMIC CONSIDERATIONS

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

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

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

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

GEOSCIENCE AUSTRALIA GUIDELINES FOR CLASSIFYING MINERAL RESOURCES

- (i) Use of the term 'resources' is restricted to material, the extraction of which is generally judged to be potentially economically viable in an arbitrary time frame of about 20 to 25 years. The term includes, where appropriate, material such as tailings and slags. The definition does not intend to imply that exploitation of any such material will take place in that time span, but only that its possibility might reasonably be considered. This guideline attempts to establish a lower limit to what is worth assessing. It should be applied on a commodity by commodity basis to take account of prevailing and prospective technologies. Material falling outside the category of resource should be referred to as 'occurrences'. Unless otherwise stated, the classification system refers to in situ resources. However, it is possible and in fact desirable to also show recoverable quantities of resources in each category.
- (ii) By definition, inferred resources are classified as such for want of adequate knowledge and therefore it may not be feasible to differentiate between economic and subeconomic inferred resources. Where inferred resources are shown as 'undifferentiated', the amount known or judged to be economic may be indicated. Such judgements must take careful account of the commodity being assessed and its mode of occurrence as these factors will have a bearing on the reliability of estimates made. Specifically, grade estimates can be more reliably made for concordant sedimentary and biological deposits than for discordant epigenetic deposits (King et al. 1982, p. 8).
- (iii) The definition of 'economic' is based on the important assumption that markets exist for the commodity concerned. All deposits which are judged to be exploitable economically at the time of assessment, whether or not exploitation is commercially practical, are included in the economic resources category. It is also assumed that producers or potential producers will receive the 'going market price' for their production. The classification is therefore based on the concept of what is judged to be economic rather than what is considered to be commercial at any particular time.

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

- (a) the resources (published or unpublished) of operating enterprises, whether or not such operations are sustained by long- or short-term, direct or indirect, government subsidies;
 - (b) resources in a deposit which is being developed for production (ie. where there is a corporate commitment to production);
 - (c) undeveloped resources which are judged to be economic on the basis of a financial analysis using actual, estimated, or assumed variables – viz., the tax rate, capital and operating costs, discount rate (such as reflects the long-term bond rate), commodity prices, and depreciation schedules; the values for the economic variables used in an assessment must be realistic for the circumstances prevailing at the time of the assessment;
 - (d) resources at mines on care-and-maintenance meeting the criteria outlines in (c) above.
- (iv) The term 'Recoverable resources' is used when allowance has been made for mining as well as processing losses. 'Mineable resources' is used when allowance has been made for mining losses only. For coal, these terms are used differently – the term 'Recoverable coal resources' is used when allowance has been made for mining losses only. 'Saleable coal' is used when allowance has been made for mining as well as processing losses.
- (v) Some minerals derive their economic viability from their co-product or by-product relationships with other minerals. Such relationships and assumptions must be clearly explained in footnotes or in accompanying text.
- (vi) National aggregates of resource estimates should be rounded to the appropriate last significant digit, so as not to create false impressions of accuracy.

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Appendix 3

Staff and Commodity Responsibilities: AIMR 2005 and Related Projects

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