Australian Government

Geoscience Australia

AUSTRALIA'S IDENTIFIED MINERAL RESOURCES **2009**

Australian Government
Geoscience Australia
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FRONT COVER: Iron ore loading at Cape Lambert port facilities, Western Australia (Rio Tinto Iron Ore).

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Foreword

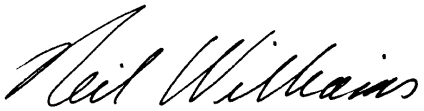
Geoscience Australia provides important information on Australia's future mineral production capacity. Australia's Identified Mineral Resources is an annual nation-wide assessment which takes a long term view of what is potentially economic. Data on mining company estimates of ore reserves, which are 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 an analysis of mineral exploration expenditure across Australia and consideration of resource lives for major commodities. Comparable information on petroleum resources is published in another Geoscience Australia publication, Oil and Gas Resources of Australia.

Australia's Identified Mineral Resources provides information on Australia's known mineral endowment, long term resource trends, the levels of exploration activity and industry developments. It provides an authoritative overview for developing government resources policies and programs and is also used by the industry, the investment sector and general community.

Australia's resource stocks remain healthy overall. Reflecting strong world demand for mineral resources, expansions in mine production of bauxite, coking coal, iron ore and other commodities continued in 2008. Despite the onset of the global financial crisis in the latter part of 2008, the mining industry still contributed substantively to Australia's prosperity. Data from the Australian Bureau of Agricultural and Resource Economics (ABARE) indicate that earnings from Australia's minerals exports (excluding oil and gas) increased by 44% to $130.3 billion in 2008.

The ability of Australia's minerals sector to maintain its highly competitive base of world class mineral resources is dependent on effective exploration leading to the discovery of new world class ore deposits. Successful exploration outcomes rely heavily on continuing updates of pre-competitive geoscience data by government agencies. State-of-the-art geoscientific syntheses and integrated research are needed to reduce exploration risks in prospective frontier regions.

Australia's Identified Mineral Resources and other fundamental data on the minerals sector can be accessed through the online Atlas of Australia's Mineral Resources, Mines and Processing Centres (www.australianminesatlas.gov.au). The atlas has a web-based geographic information system format and shows the location of mineral and energy resources, mines and production/processing centres.



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Executive Summary

Australia's Economic Demonstrated Resources (EDR) for the following 18 mineral commodities increased during 2008 — black coal, copper, gold, iron ore, lead, lithium, manganese ore, molybdenum, nickel, niobium, rare earth oxides, silver, tantalum, tungsten, uranium, vanadium, zinc and zircon. In the same period, EDR of nine commodities decreased — brown coal, cobalt, diamonds (gem and industrial), mineral sands (ilmenite and rutile), platinum group elements, shale oil and tin. EDR for antimony, bauxite, cadmium, magnesite, and phosphate rock remained at levels similar to those reported in 2007.

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

Australia's EDR of **bauxite** were estimated to be 6.2 gigatonnes (Gt) in 2008 which is unchanged from the previous year and ranks second largest in the world. Australia's aluminium industry is underpinned by vast resources of bauxite in Queensland (Qld) on western Cape York, and in Western Australia (WA) in the Darling Range, which are among the world's largest identified resources. Despite the economic downturn, large companies have maintained overall production levels. Steadily increasing investment from China has accelerated changes in Australia's bauxite exploration, mining and processing industries in recent years.

Recoverable EDR of **black coal** in 2008 increased 0.8% to 39.2 Gt which represents 6% of the world's recoverable black coal EDR and ranks Australia as having the world's sixth largest EDR. The Sydney Basin in New South Wales (NSW) contains 35% of Australia's recoverable EDR and the Bowen Basin in Qld contains 34%. Recoverable EDR of **brown coal** in 2008 was 37.2 Gt, slightly less than 2007 and represents about 25% of the world's recoverable brown coal, the largest of any country. All of Australia's brown coal EDR is in Victoria (Vic).

At December 2008 the proven and probable (2P) reserves of **coal bed methane** in Australia were 16 179 Petajoules (PJ), an increase of 116% over the 2P reserves at December 2007. Queensland has 15 302 PJ (or 94.6% of the 2P reserves) with the remaining 877 PJ in NSW.

Australia's EDR of **copper** rose by 31% to 77.8 million tonnes (Mt) in 2008, largely resulting from the release of updated resource estimates for the Olympic Dam deposit in South Australia (SA). Australia has the world's second largest EDR after Chile. South Australia has the dominant share of Australia's EDR with 73% of the national total, almost all of this is in Olympic Dam deposit. By late 2008 significantly lower copper prices had forced several copper mines to cease production, particularly the smaller or lower grade operations.

Australia's **gold** resources occur and are mined in all States and the Northern Territory (NT). Australia's EDR of gold rose by 7% in 2008 to 6255 tonnes, the second largest globally. Western Australia has the dominant share with 47% of the national total EDR.

In 2008, EDR of **iron ore** increased by 18% to 24 Gt which is about 15% of world EDR, and the world's third largest. Western Australia has 98% of Australia's EDR with about 86% occurring in the Pilbara district.

Australia's EDR of **manganese ore** increased by 9.9% during 2008 to 181 Mt, which represents about 13% of the world's EDR of manganese ore and ranks Australia as having the world's fourth largest EDR. The Groote Eylandt deposit in the NT had 70% of the total manganese ore EDR.

The regions containing the major proportion of Australia's **mineral sands** resources (ilmenite, rutile and zircon) are the Perth Basin north of Perth in WA, the Murray Basin (NSW, Vic, and SA) and the newly emerging heavy mineral sands regions in the Eucla Basin (WA and SA). Although the reduced demand for mineral sands products as a result of the global financial crisis commencing in late 2008 placed some operations under stress, new mining operations are being commissioned. In 2008, EDR

of ilmenite decreased by 4.1% to 212.3 Mt, EDR of rutile decreased by 0.9% to 22.9 Mt, and EDR of zircon increased slightly to 39.2 Mt. Rutile and zircon resources rank first in the world while ilmenite resources are the second largest worldwide.

Australia's EDR of **nickel** increased by 2.3% to 26.4 Mt in 2008, which is the world's largest EDR. Western Australia remains the largest holder of nickel resources with 90.4% of total Australian EDR, comprising both sulphide and lateritic deposits. The combination of the global financial crisis and falling nickel prices led to a number of mine closures.

Australia's EDR of **rare earth oxides** were 1.65 Mt. Significant resources of rare earths are contained in the monazite component of heavy mineral sand deposits, which are mined for their ilmenite, rutile, leucoxene and zircon content. Currently, extraction of rare earths from monazite sands is not viable because of the cost involved with the disposal of thorium and uranium present in the monazite.

Oil shale resources are predominantly in a series of sedimentary basins near Gladstone and Mackay in central Qld. The Permian Galilee and Bowen Basins in Qld contain oil shale associated with coal measures. Australia currently has no EDR of oil shale, with all resources being assessed as subeconomic.

Australia's EDR of **tantalum** increased 21% to 51 kilotonnes (kt) in 2008, ranking it second largest globally. The overwhelming majority of resources are in WA. In December 2008, the world's largest tantalum producer, Talison Minerals, suspended mining at Wodgina in WA, because of a fall in demand for Australia's tantalum metal caused by the supply of cheaper tantalum concentrates from largely artisan type mining operations in Central Africa.

Australia's EDR of **uranium** at December 2008 were estimated to be 1.163 Mt U, an increase of 18% during the year, by far the highest of any country. This was due to a large increase in resource estimates for the Olympic Dam deposit in SA and increased resources at the Ranger 3 Deeps ore zone in the NT.

Australia's EDR of **zinc** increased by 26.2% to 53.1 Mt in 2008, the largest in the world. Increases in resources were associated with a new resource estimate for the Dugald River deposit in Qld and a reassessment of resources at McArthur River in the NT. By late 2008 markedly lower zinc and lead prices had impacted significantly on almost all zinc-lead mines. Many scaled back throughput and refocused mining in higher grade resources. Some moved to care and maintenance. Australia's EDR of **lead** increased by17.4% in 2008 to 26.8 Mt, while EDR for **silver** increased by 22.6% in 2008 to 61.4 kt; both are the largest EDR in the world.

Resource life: Ratios of accessible Economic Demonstrated Resources (AEDR) to current mine production provide indicative estimates of the resource life. AEDR of most of Australia's major commodities can sustain current rates of mine production for many decades. Resource life based on ore reserves is lower, reflecting a shorter term commercial outlook.

Over the decade 1997 to 2008 there has been a significant trend towards lower AEDR/production ratio for coal and iron ore, which was the nett result of major increases in production and reassessment of resources.

Commodities with resource life of less than 50 years are diamonds (about 10 years at current rates of production), manganese ore (20 years), gold (30 years), zinc (35 years) and lead (40 years).

The severe world financial crisis in late 2008 highlighted the fact that a long resource life for a particular commodity is not a guarantee that such resources will continue to be exploited in Australia. In an increasingly globalised and competitive commodity market, multinational mining companies are continually in search of mineral deposits that will offer attractive returns on their investment. Such returns are influenced by the quality of the resources (grade and tonnage) as well as environmental, social and political factors, land access and even the location and scale of the competitor projects – individual mine projects in Australia will be ranked by multinational corporations against the investment returns from other deposits worldwide.

Australia's continuing position as a premier mineral producer is dependent on continuing investment in exploration to locate high quality resources and/or to upgrade known deposits in order to make them competitive on the world market, and investment in beneficiation processes to improve metallurgical recoveries.

Introduction

Geoscience Australia and its predecessors have prepared annual assessments of Australia's mineral resources since 1975. The resource data and related information from *Australia's Identified Mineral Resources* provide input into Australian Government policy decisions and programs associated with the minerals sector, sustainable development of resources and financial allocations. They are reproduced by the Australian Bureau of Statistics.

Australia's Identified Mineral Resources 2009 presents estimates of Australia's mineral resources at end of December 2008 for all major and several minor mineral commodities (Table 1) based on published and unpublished data available to Geoscience Australia. These resource estimates provide a long term view of what is likely to be mined. They are compared with national totals of ore reserves for each commodity, which provides the industry view of what is likely to be mined in the short to medium term. Mine production data are based on the Australian Bureau of Agricultural and Resource Economics figures. World ranking of Australia's mineral resources have been calculated mainly from information in publications of the United States Geological Survey. A summary of significant industry developments also is presented.

Australia's Identified Mineral Resources 2009 provides information on and analysis of mineral exploration expenditures in Australia for 2007–08 and the calendar year 2008. Trends in expenditure are presented and discussed.

National Resource Classification System

The mineral resource classification system 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.

For a full description of the system see Appendix 2 'National classification system for identified mineral resources'.

The description of the National Classification System has been revised to clarify how mineral resources reported by companies under the ***Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves*** (referred to as the JORC Code) are used when compiling national total resources. The classification category 'Economic Demonstrated Resources' is used for national totals of economic resources and provides a basis for meaningful comparisons of Australia's economic resources with those of other nations. Long-term trends in EDR for bauxite, black coal, iron ore, gold, copper, nickel, lead, zinc, mineral sands and uranium are presented and the reasons for significant changes in resource trends are noted.

In recent years, the ability of the Australian, State and Northern Territory governments to access mineral resource data and analyse trends has been inhibited by the rapid increase in the number of foreign-listed, private and private equity companies involved in mining and mineral exploration in Australia. Only companies listed on the Australian Securities Exchange (ASX) are required to publicly report on the ore reserves and mineral resources they control. As public reporting provides the basic information for the national minerals inventory, the Ministerial Council on Mineral and Petroleum Resources has established a Resource Reporting Committee to prepare recommendations in relation to reporting on mineral resources and mine production controlled by companies not listed on the ASX. Geoscience Australia is participating in the work of the committee.

Accessible Resources

Some mineral deposits are not accessible for mining currently because of government policies or various environmental and land-access restrictions such as location within National/State parks and conservation zones, military training areas or environmental protection areas as well as areas over which mining approval has not been granted by traditional owners. Accessible Economic Demonstrated Resources as shown in Table 1 represent the resources within the EDR category which are accessible for mining. It should be noted that the factors which restrict access for mining could change in the future.

Resource Life

The national total ore reserves (OR) figures shown in Table 1 are derived from estimates prepared by companies for mine planning and marketing purposes and generally have a shorter term outlook than EDR. The ratios of EDR/production, AEDR/production and OR/production 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, with OR/production being the most conservative. The ratios can vary quite rapidly as a result of major changes in production rates and/or resource stocks.

Notes for Table 1

Abbreviations: t = tonne; m^3 = cubic metre; L = litre; kt = 10^3t; Mc = 10^6 carat; Mt = 10^6t; Gt = 10^9t; GL = 10^9L.

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) Proved 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 2008, mostly USGS estimates.

g) Black and brown coal reserves include both JORC reserves and Geoscience Australia estimated reserves for operating mines that do not publish JORC reserves.

h) Raw coal.

i) Geoscience Australia estimate.

j) Saleable coal.

k) Excludes Morocco and USA.

l) 239 528 t of spodumene concentrate from Western Australian Department of Mines and Petroleum.

m) Excludes USA.

n) Not reported by mining companies.

o) Production of phosphate rock at Duchess mine (Qld) for 2007-08. Production data for Christmas Island not available for commercial-in-confidence reasons.

p) Total Inferred Resource excludes a 'total potential' shale oil resource of the Toolebuc Formation, Queensland of 245 000 GL that was estimated by the Bureau of Mineral Resources and CSIRO in 1983.

q) Source: World Energy Council (WEC) Survey of Energy Resources 2007.

r) Latest production figures for end 2005 from WEC Survey of Energy Resources 2007.

s) Tantalum production from Western Australian Department of Mines and Petroleum.

t) Thorium resources reduced by 10 per cent to account for mining and processing losses.

u) Source: OECD/NEA & IAEA (2007). Compiled from the most recent data for resources recoverable at costs of less than US$80/kg U.

v) Source: World Nuclear Association.

Table 1. Australia's resources of major minerals and world figures as at 31 December 2008.

COMMODITY	UNITS	AUSTRALIA							WORLD	
		Demonstrated Resources			Inferred Resources (a)	Accessible EDR (AEDR)(b)	JORC Reserves(c) *(% of AEDR)*	Mine Production(d) 2008	Economic Demonstrated Resources(e)	Mine Production(f) 2008
		Economic (EDR)	Subeconomic							
			Para-marginal	Sub-marginal						
Antimony	kt Sb	136	43	36	60	136	96 (70%)	–	2100	135
Bauxite	Gt	6.2	0.2	1.4	0.91	5.4	1.9 (35%)	0.064	27	0.205(e)
Black coal -										
In situ	Gt	56.2	3.0	10.3	106.0					
Recoverable	Gt	39.2	1.5	6.7	66.7	39.1	13.4(g) (34%)	0.425(h)	681(i)	5.7(i)(j)
Brown coal -										
In situ	Gt	44.3	43.1	18.1	112.3					
Recoverable	Gt	37.2	38.8	16.3	101.1	32.2	4.8(g) (15%)	0.066(i)	147(i)	0.87(i)
Cadmium	kt Cd	60.8	10.0	10.2	0.3	60.8	51.3 (84%)	0.46	490	19.9(m)
Cobalt	kt Co	1495	154	101	1915	1495	485 (32%)	4.79	7095	70.3
Copper	Mt Cu	77.8	6.6	1.0	34.2	77.8	19.8 (25%)	0.89	603	15.7
Diamond -										
Gem & near gem	Mc	91.9	99.7	0	14.3	91.9	91.2 (99%)	7.7	–	101
Industrial	Mc	95.7	103.8	0	14.9	95.7	94.9 (99%)	8.0	586	67
Fluorine	Mt F	–	0.5	0.1	2.8	–	–	–	117(k)	2.7
Gold	t Au	6255	1478	123	4596	6130	3409 (54%)	215	48 655	2407
Iron ore	Gt	24.0	0.3	1.6	28.9	23.9	10.8 (45%)	0.341	158	2.2
Lead	Mt Pb	26.8	6.6	0.5	18.6	26.8	10.7 (40%)	0.65	82	3.9
Lithium	kt Li	584	0	25	25	584	–	(l)	4514	27.4(m)
Magnesite	Mt $MgCO_3$	344	22	35	931	344	37.5 (11%)	0.126	7630	15.48(m)
Manganese ore	Mt	181	23	167	133	181	152 (84%)	4.8	1370	41
Mineral sands -										
Ilmenite	Mt	212.3	23.8	0.1	123.2	175.9	42.7 (24%)	2.042	1266	10.4
Rutile	Mt	22.9	6.5	0.15	32.1	17.2	5.1 (30%)	0.325	46	0.6(m)
Zircon	Mt	39.1	9.8	0.15	36.5	30.9	9.7 (31%)	0.550	87	1.75
Molybdenum	kt Mo	225	101	260	644	225	223.1 (99%)	–	8600	212
Nickel	Mt Ni	26.4	1.1	1.0	20.9	26.4	7.1 (27%)	0.2	69.9	1.6
Niobium	kt Nb	115	29	0	811	115	–	(n)	2700	60
Phosphate rock	Mt	81.6	997.04	–	1574	81.6	81.6 (100%)	2.154(o)	15 000	167
PGM (Pt, Pd, Os, Ir, Ru, Rh)	t metal	18.9	118.5	35.3	145.3	14.6	0.12 (1%)	0.710	71 000	406
Rare earths (REO & Y_2O_3)	Mt	1.65	0.36	34.30	20.17	1.65	0 (–)	0 (–)	84	1.97
Shale oil	GL	–	213	2074	1272(p)	–	–	0	449 266(q)	0.859(r)
Silver	kt Ag	61.4	14.7	3.5	30.0	61.4	26.2 (43%)	1.93	302	21.0
Tantalum	kt Ta	51	15	0.3	80	51	19 (37%)	0.680(t)	130	1.058
Thorium	kt Th	–	75.7(t)	–	413.7(t)	–	–	–	–	–
Tin	kt Sn	145	59	48	429	145	57 (39%)	1.783	5660	332
Tungsten	kt W	111.5	10.0	10.9	73.5	111.5	10.7 (9.6%)	0.008	3000	54.6
Uranium	kt U	1163	13	3	500	1062	264 (25%)	8.432	3047(u)	44.019(v)
Vanadium	kt V	1750	10	4124	3759	1750	991 (57%)	0	13 000	60
Zinc	Mt Zn	53.1	7.2	1.4	21.9	53.1	20.2 (42%)	1.52	193	11.3

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 1975–2008 (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 of resources 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 previously were uneconomic,
- adoption of the JORC Code[1] for resource classification and reporting by the Australian minerals industry and the subsequent impacts on re-estimation of ore reserves and mineral resources to comply with the requirements of the Code. Many companies re-estimated their mineral resources to comply with the Code and some re-assessment was made of resource data for other deposits by Geoscience Australia's predecessor, the 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.

Bauxite

Increases in bauxite EDR in 1989 resulted from delineation of additional resources in deposits on Cape York Peninsula ('a' 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 ('b').

Black Coal

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

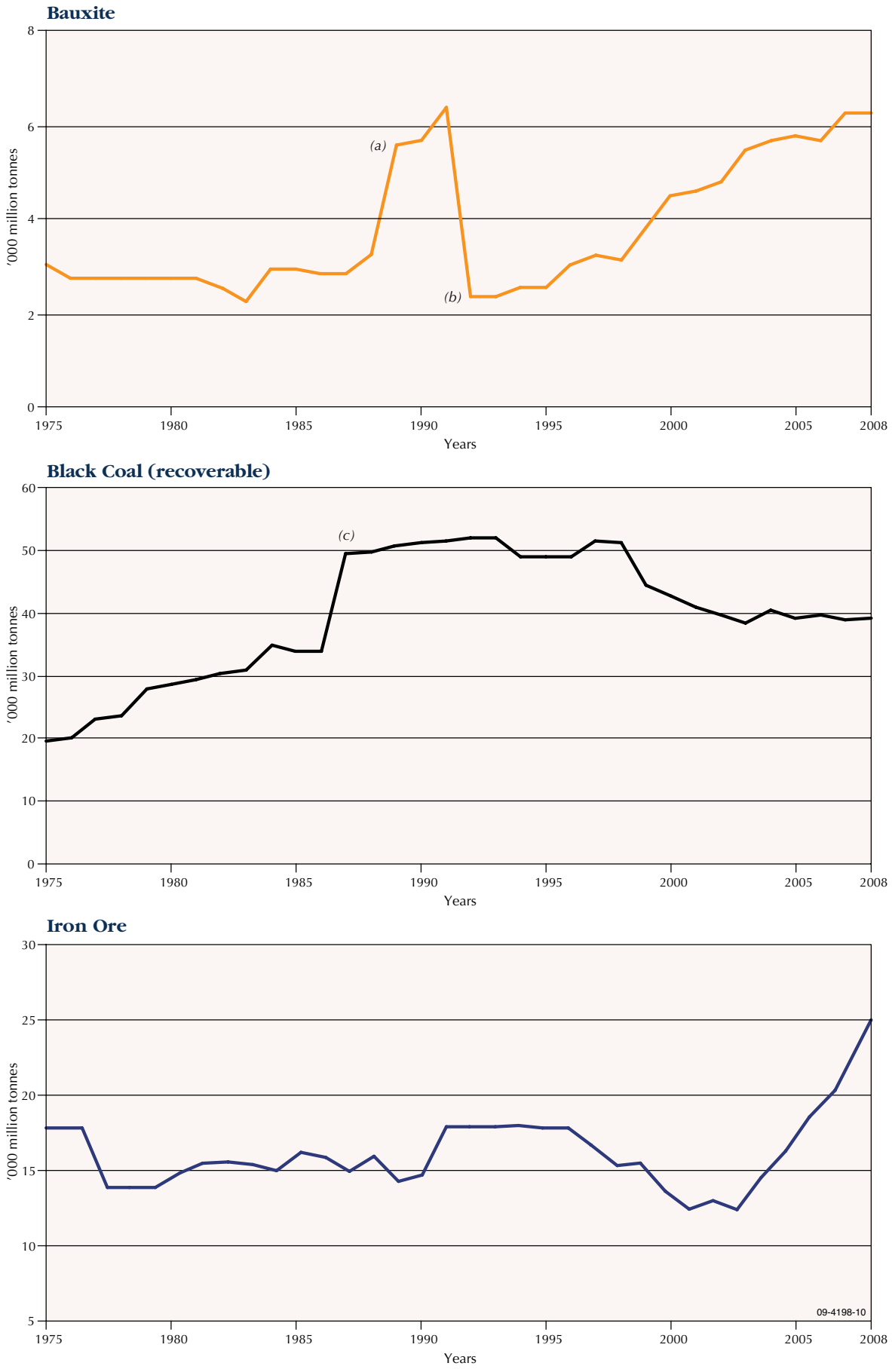
EDR for black coal has declined since 1998 due to the combined impacts of mining companies re-estimating ore reserves and mineral resources more conservatively so as to comply with requirements of the JORC Code, and increased rates of mine production.

Iron Ore

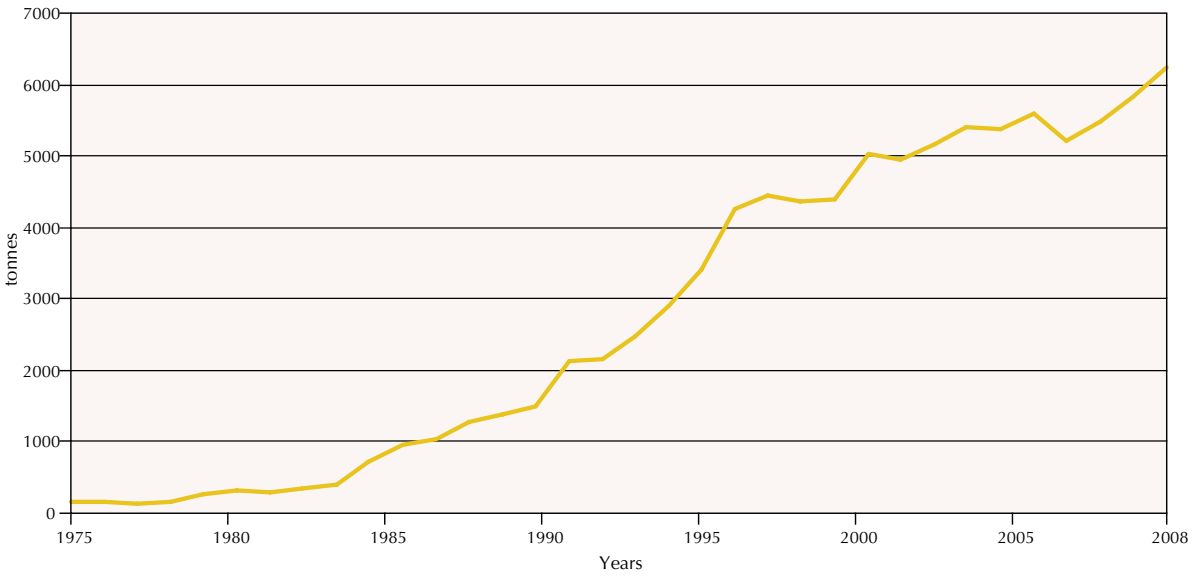
EDR for iron ore declined from 1996 to 2001 due to the combined impacts of mining companies re-estimating ore reserves and mineral resources more conservatively so as to comply with requirements of the JORC Code, and increased rates of mine production. However since 2003 EDR has increased due to reclassification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

1 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.

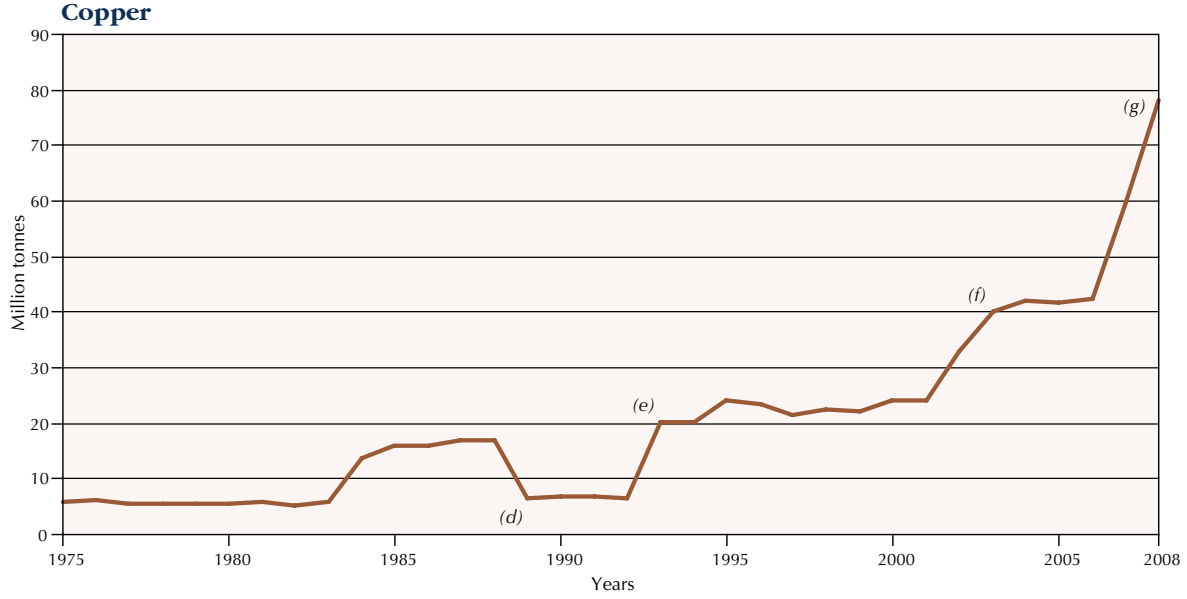
Figure 1: Trends in Economic Demonstrated Resources for major commodities since 1975.



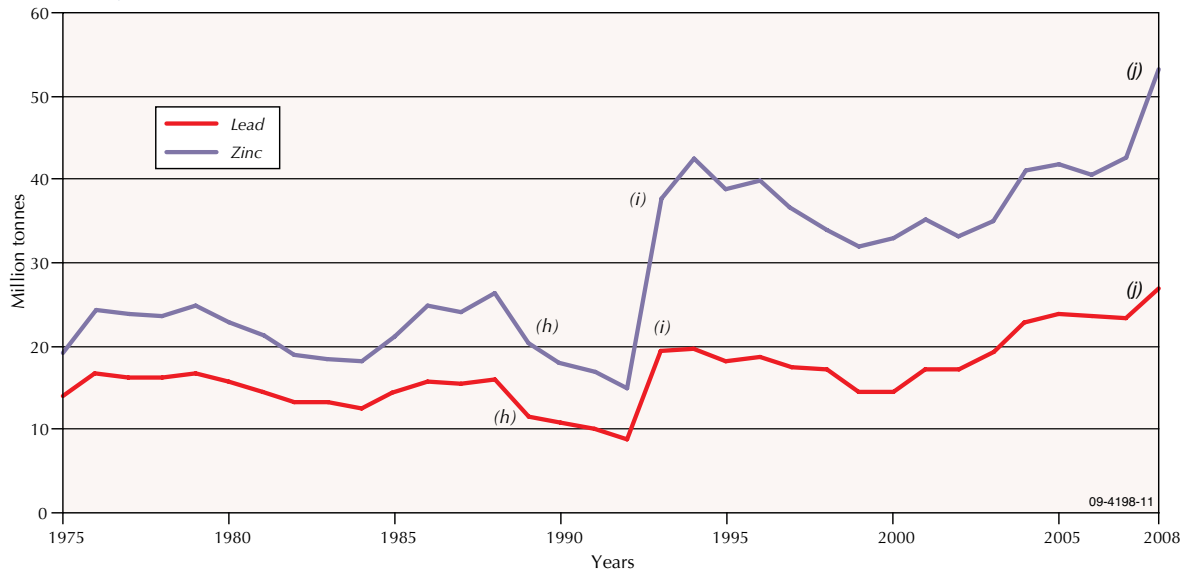
Gold



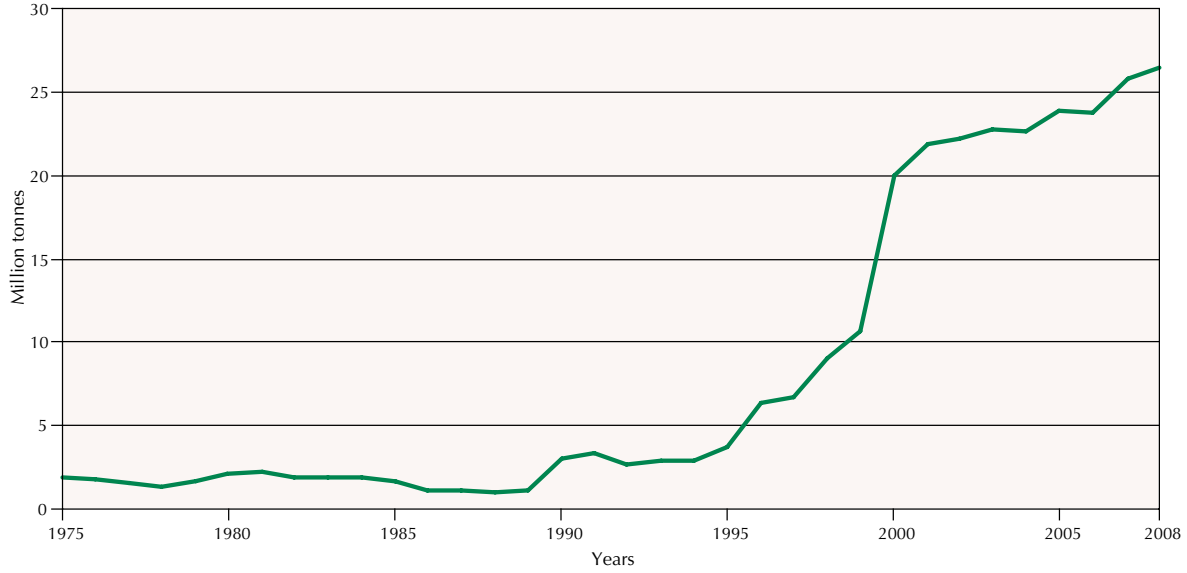
Copper



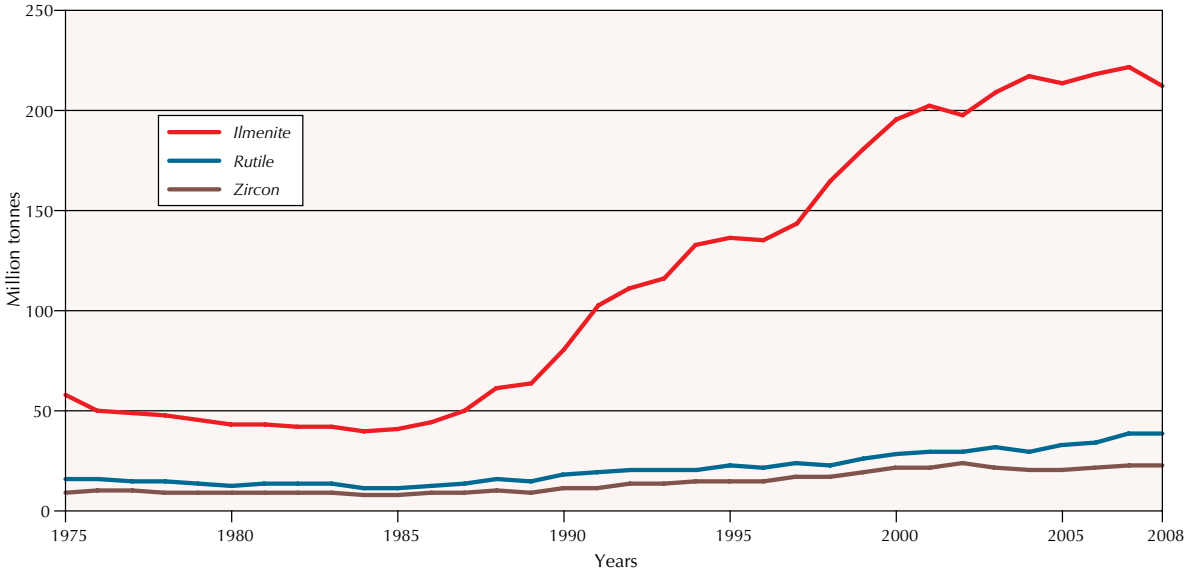
Lead, Zinc



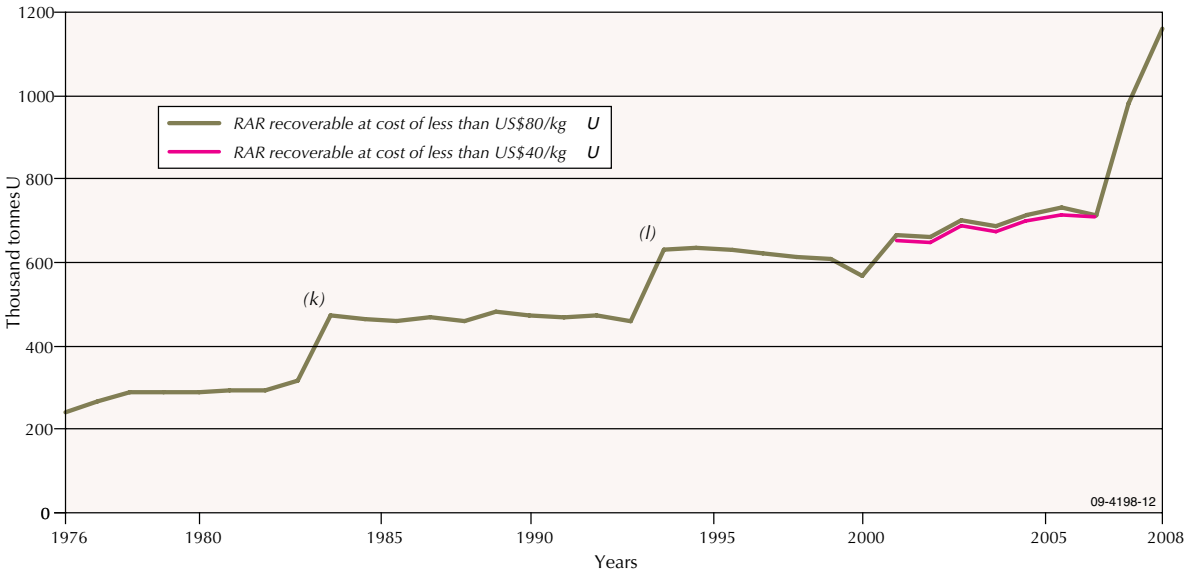
Nickel



Mineral Sands



Uranium (recoverable)



Gold

Gold EDR has increased steadily since 1975 with a clear increase in the rate of growth since 1983. 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.

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'). In 2007 and 2008, copper resources increased sharply mainly due to a large increase in resources for Olympic Dam ('g'). Drilling over recent years has outlined large resources in the south eastern part of the deposit.

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 ('h').

Increases in EDR for lead and zinc in 1993 were due to re-classification of paramarginal demonstrated resources into EDR for McArthur River (NT) and George Fisher deposits (Qld). Additional resources were also reported for Century and Cannington deposits (Qld) ('i').

Increases in 2008 were associated with reassessment of resources at the McArthur River mine (NT), where an expansion from underground to open cut mining was approved, and reassessment of the Dugald River deposit (Qld) for which a new and increased resource estimate was released ('j').

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 other lateritic deposits in the Kalgoorlie region (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 further increases in total EDR for sulphide deposits at Perseverance, Sally Malay, Maggie Hays, Anomaly 1, Honeymoon Well, deposits in the Forrestania area as well as new deposits at Prospero and Tapinos (all in WA), Avebury (Tas), and remnant resources at several sulphide deposits in the Kambalda region including Otter-Juan and Lanfranchi groups of deposits.

From 2001 onwards EDR increased at a slower rate because: 1) absence of further discoveries of lateritic nickel deposits, and 2) 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.

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 New South Wales (Gingko, Snapper), Victoria (Douglas-Bondi, Woornack), and South Australia (Mindarie project). In addition, from 1998 onwards there were progressive increases in resources at mineral sands deposits at Ambrosia-Jacinth and Cyclone in the Eucla Basin (South Australia and Western Australia), in the North Swan Coastal Plain area north of Perth, and the Blackwood Plateau region (includes the Beenup deposit) in Western Australia.

Uranium

The majority of Australia's uranium deposits were discovered between 1969 and 1975 – approximately 50 deposits (15 with significant resource estimates) were discovered during this short period. Since 1975, only another five deposits have been discovered – of these, only three deposits (Kintyre in the Paterson Province WA, Junnagunna, north west Qld and Four Mile SA) have Reasonably Assured Resources recoverable at less than US$80/kg U (equates with EDR). Hence, the progressive increases in Australia's EDR for uranium from 1975 to the present (as shown in Fig. 1) were largely due to on-going delineation of resources at known deposits.

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

- in 1983, initial resource estimates for Olympic Dam and Ranger No. 3 Orebody (NT) made by the former Australian Atomic Energy Commission ('k').
- in 1993, further increases in EDR for Olympic Dam and first assessment of resources for the Kintyre deposit by the former Bureau of Mineral Resources ('l').
- in 2000, increases were due to continuing additions to the Olympic Dam resources.
- in 2007 and 2008, major increase in EDR for Olympic Dam. Drilling in recent years has outlined major extensions to the south eastern part of the deposit.

COMMODITY REVIEWS

West Angelas iron ore open cut mine, Western Australia (Rio Tinto)

Bauxite

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Bauxite is a heterogeneous naturally occurring material from which alumina (Al_2O_3) and aluminium metal are produced. The principal minerals in bauxite are gibbsite ($Al_2O_3.3H_2O$), boehmite ($Al_2O_3.H_2O$) and diaspore, which has the same composition as boehmite, but is denser and harder.

Australia is the world's largest producer of bauxite, with 31% of global production in 2008. The bauxite resources at Weipa in Queensland (Qld) and Gove in the Northern Territory (NT) have almost 50% available alumina and are amongst the world's highest grade deposits. Other deposits located in Western Australia's (WA) Darling Range, Mitchell Plateau and Cape Bougainville, the latter two of which have not been developed, are relatively low grade at around 30% available alumina.

More than 85% of the bauxite mined globally is converted to alumina for the production of aluminium metal. An additional 10% goes to non-metal uses in various forms of specialty alumina while the remainder is used for non-metallurgical bauxite applications. In most 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 highly integrated sector of mining, refining, smelting and semi-fabrication centres and is of major economic importance nationally and globally. The industry consists of five bauxite mines, seven alumina refineries, six primary aluminium smelters, 12 extrusion mills and two rolled product (sheet, plate and foil) mills. The industry in Australia is geared to serve world demand for alumina and aluminium with more than 80% of production exported. Figures on the value of industry exports are collated half-yearly by the Australian Bureau of Statistics (ABS) and the Australian Bureau of Agricultural and Resource Economics (ABARE) publishes quarterly production and export data on bauxite, alumina and aluminium.

Resources

The long-term future of Australia's aluminium industry is underpinned by vast resources of bauxite located in the Weipa and Gove regions adjacent to the Gulf of Carpentaria in the NT, and the Darling Range south of Perth, WA. Deposits in these regions rank among the world's largest identified resources in terms of extractable alumina content. The undeveloped bauxite deposits at Mitchell Plateau and Cape Bougainville in northern WA are not currently economic to develop, but are a significant potential future resource.

Economic Demonstrated Resources (EDR) of 6.2 gigatonnes (Gt) in 2008 remained consistent with the previous year. The nett change in overall demonstrated resources was minor with additions resulting from exploration drilling being offset by depletions created through mine production.

Accessible Economic Demonstrated Resources (AEDR)

About 95% of bauxite EDR is accessible for mining. Some areas within mining leases in the Darling Range in WA in particular are not available for extraction for environmental reasons. The ratio of AEDR to current mine production shows the resource life of existing bauxite operations is around 70 years. Significant potential exists for further mineral exploration and reserve delineation to extend the current resource life estimate.

JORC Reserves

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

Exploration

Data on exploration for bauxite specifically are not available nationally.

Production

Australia was the leading producer of bauxite and alumina globally in 2008, and the fifth largest aluminium producer. Production totalled 63.8 million tonnes (Mt) of bauxite (31% of world production), 19.7 Mt of alumina (33%) and 2 Mt of aluminium (8%). However, significant declines in the prices obtained for bauxite, alumina and aluminium since mid-2008 are not yet fully reflected in the Institute data. Expansion of the Weipa (Qld) bauxite production operations south of the Embley River is under consideration, including the potential for construction of a new deepwater port. Other bauxite extraction projects are under consideration on Cape York Peninsula (Qld) and the Darling Range area (WA).

World Resources

Based on United States Geological Survey (USGS) data for other countries, Australia's demonstrated bauxite resources of 7.8 Gt rank second in the world after the Republic of Guinea and ahead of Vietnam, Brazil, Jamaica and China.

Industry Developments

Aluminium is a product of increasing importance for manufacturing because of its light weight, strength and durability as well as its capacity to be recycled. On a life cycle assessment basis, the high strength to weight ratio of aluminium results in significant fuel savings, particularly where substitution can be made for heavier construction materials.

The expansion of Australian bauxite, alumina and aluminium production in the past few years reflects high demand for the commodities and all three maintained high levels of production during 2008, with significant investments being undertaken in prospective projects. Along with the well developed production areas around Weipa (Qld), Gove (NT) and the Darling Range (WA), bauxite occurrences on the Mitchell Plateau and Cape Bougainville (WA), Cape York (Qld) and central New South Wales (NSW) maintained sector interest.

Black Coal

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Coal is a fossil fuel of sedimentary origin that has formed by coalification of vegetation over millions of years. Black coal consists of the higher rank coals including anthracite, bituminous and sub-bituminous coals. In Australia, black coal deposits occur in all States and the Northern Territory and range in age from 140 to 225 million years old. Black coal is primarily used as a fuel to generate electricity and produces about 80% of Australia's electricity requirements. Black coal is used to produce coke also for the steel making process and by-products of coke-making include coal tar, ammonia, lights oils and coal gas. Other uses for black coal include cement manufacturing, food processing, paper manufacturing and alumina refineries.

Queensland (Qld) produces 54% and New South Wales (NSW) produces 43% of Australia's black coal while locally significant production occurs at Collie in Western Australia (WA), Leigh Creek in South Australia (SA) and in the Fingal Valley and at Kimbolton in Tasmania.

Resources

Recoverable economic demonstrated resources (EDR) in 2008 increased 0.8% to 39.2 gigatonnes (Gt) due mainly to significant increases at Mt Arthur, Belvedere, Blackwater, Saraji and Wandoan. New resources were announced at Cherry Tree Hill and Washpool. Significant decreases occurred at Kevins Corner and Peak Downs. Queensland (56%) and New South Wales (40%) had the largest share of recoverable EDR in Australia. The Sydney Basin (35%) and Bowen Basin (34%) contain most of the recoverable EDR in Australia.

In 2008, the recoverable paramarginal demonstrated resources (PDR) decreased about 32% to 1.5 Gt, mainly as a result of reclassification of resources. The recoverable subeconomic demonstrated resources (SDR) remained constant at 6.7 Gt. The recoverable inferred resources increased 9.2% to 66.7 Gt. Large increases in inferred resources occurred at Warkworth, Alpha, Blackwater, Kevins Corner, North Alpha, South Alpha and Wandoan. Inferred resources were included for the first time at Oaklands North, Arcadia, Arcturus, Dingo West, Red Hill (Aquila) and Washpool. In the five years to December 2008 recoverable inferred resources have increased from 52.7 Gt to 66.7 Gt, or about 26%.

Accessible EDR

Nearly all black coal EDR is accessible with only a relatively small tonnage at Hill River (WA) being quarantined within State Reserves. The resource life of the accessible EDR of 39.1 Gt was about 90 years at current rates of production.

JORC Reserves

JORC reserves are 13.4 Gt or 34% of accessible EDR. Included in the 13.4 Gt are Geoscience Australia estimates of reserves at some operating mines that had no reported JORC reserves. This constituted 1.9 Gt or about 14% of JORC reserves. BHP Billiton, Rio Tinto and Xstrata Coal manage about 57% of JORC reserves in Australia. The resource life of the JORC reserves of 13.4 Gt is 31 years.

Exploration

Data published by ABS on coal indicated that exploration expenditure for 2008 totalled $276.3 million which is an increase from $192.6 million in 2007. Expenditure in Qld was $161.7 million or 59% of the total and was $93.7 million in NSW or 34% of the total. Exploration also occurred in SA, WA, Tasmania and Victoria. In 2008, coal exploration expenditure contributed 10.6% to the total exploration expenditure in Australia.

Production

In 2008, Australia produced 425 million tonnes (Mt) of raw coal (416 Mt in 2007) which yielded 328 Mt of saleable coal (322 Mt in 2007). Exports of black coal during 2008 were 134.8 Mt of coking coal valued at $32.1 billion and 126.3 Mt of thermal coal valued at $14.4 billion. The Australian Bureau of Agricultural and Resource Economics (ABARE) has projected that Australia's saleable production will grow to 404 Mt by 2014. Exports of coking and thermal coals are projected to increase to 162 Mt and 163 Mt respectively by 2014.

World ranking

Australia has 6% of the world's recoverable black coal EDR and ranks sixth behind USA (31%), Russia (21%), China (13%), India (8%) and South Africa (7%).

Australia produced about 6% of the world's black coal in 2008 and ranked fourth after China (45%), USA (18%) and India (8%).

Industry Developments

OVERVIEW

A number of projects were commissioned during 2008, including Lake Vermont (**Lake Vermont Resources**), Glendell (**Xstrata**), Abel (**Donaldson Coa**l), Rocglen (**Whitehaven Coa**l) and the Liddell expansion (**Xstrata**). The Stage 1 and Stage 2 expansions of the Dalrymple Bay Coal Terminal to 72 million tonnes per annum (Mtpa) were both completed in 2008. Projects under construction during 2008 included Kestrel (**Rio Tinto**), Clermont (**Rio Tinto**), Blakefield South (**Xstrata**), Mangoola (**Xstrata**), Moolarben (**Felix Resources**), NRE Wongawilli Colliery (**Gujarat NRE Resources**) and Narrabri Colliery (**Whitehaven Coal**). Construction of the Airly Colliery began in early 2009 (**Centennial Coal**). The Abbott Point, Brisbane and Kooragang Island coal terminal expansions were under construction during 2008 and construction commenced on the new 30 Mtpa coal terminal owned by the **Newcastle Coal Infrastructure Group**. There are more than 35 proposed new mines, expansions and extensions which are at stages of development ranging from scoping studies to marketing

Yarrabee coal mine, Queensland (Felix Resoures)

QUEENSLAND

Rio Tinto Coal Australia: In 2008 construction commenced on the US$991 million Kestrel Mine Extension project. The 375m wide longwall is planned to increase production from 4.0 to 5.7 Mtpa from 2012 over a 20 year mine life. The US$750 million Clermont project is under construction and production is due to commence in 2010. The open-cut mine will produce 12.2 Mtpa of thermal coal over a planned 17 year mine life. A 15 km conveyor will connect the mine to the current infrastructure at Blair Athol where production is expected to wind down by 2011.

BHP Billiton Mitsubishi Alliance (BMA Coal): Mining at the Crinum longwall mine ceased in late 2007. The roof supports were moved to the Crinum East punch longwall mine and operations commenced again in early 2008. After four years at Crinum East the roof supports will be relocated to Crinum North. The proposed 4.4 Mtpa Daunia open-cut truck and shovel mine near the Poitrel operation was expected to produce the first coal in 2010. The proposed 5.5 Mtpa Caval Ridge open-cut mine at the north end of the Peak Downs operation was expected to produce the first coal in 2011. The proposed 8 Mtpa Goonyella mine expansion from 16 to 24 Mtpa was expected to be producing coal in 2013. In July 2008, BMA Coal acquired the New Saraji project from the New Hope Corporation for US$2.4 billion.

Xstrata Coal: A pre-feasibility study of the Wandoan project was completed in late 2008. A large scale sample pit was developed in mid-2008. A feasibility study of a $1 billion 20 Mtpa open-cut thermal coal mine at Wandoan is expected to continue in 2009. A new rail connection will need to be constructed between Wandoan and the existing Moura-Gladstone rail line.

Anglo Coal: In February 2008 Anglo Coal paid $728 million for 70% of the Foxleigh mine, which is near Anglo's German Creek complex. Anglo Coal plans to increase production at Foxleigh from 2.5 to 4 Mtpa. The new coal washing plant for the Lake Lindsay mine was commissioned in March 2008. The new $210 million Moranbah North longwall is expected to be commissioned in 2009.

Macarthur Coal: The Olive Downs North box-cut is expected to commence in late 2009. Coal will be hauled to the Moorvale wash plant. A pre-feasibility study is being undertaken on the Moorvale

underground bord and pillar mine which will use direct entry from the open-cut highwall. At the $70 million Middlemount Project mining is expected to commence in late 2009 at a production rate of 1.8 Mtpa.

Wesfarmers: A $130 million project at the Curragh mine will involve the diversion of Blackwater Creek to allow access to around 47 Mt of coal. The project is expected to be completed in late 2009. The company is undertaking a feasibility study into expanding the Curragh mine to 8 Mtpa of metallurgical coal.

Felix Resources: The completion of construction of a wash plant at the Yarrabee mine in mid-2009 will enable Felix to increase production from 1.7 to 2.8 Mtpa. The 2.5 Mtpa Minerva open-cut coal mine has 11 years of life remaining with the potential to develop an underground mine at the adjacent Athena area.

Peabody Pacific: Production at the Wilkie Creek mine increased from 2.1 to 2.8 Mtpa during 2008. Peabody is proposing to increase production at the Millenium open-cut mine from 1.4 Mtpa to up to 7 Mtpa. At Eaglefield, Peabody is proposing to increase production from the open-cut mine from 3.5 Mtpa to up to 12 Mtpa.

Ensham Resources: The $600 million Ensham Central project is planned to increase production capacity from 12 to 20 Mtpa. Open-cut mining will extend to the west of the current pit and an extra 8 Mtpa will come from development of an underground longwall operation to the west of the limit of the planned open-cut extension.

Vale: In 2009, a US$138 million longwall unit will be installed at the Carborough Downs mine to increase capacity to 4.9 Mtpa. A feasibility study on the Stage 1 A$892 million Eagle Downs 4 Mtpa single longwall is expected to be completed in mid-2009. A pre-feasibility study is underway into the Belvedere project which is planned to produce up to 9 Mtpa of hard coking coal from two longwalls by 2014. A feasibility study is being undertaken on the Ellensfield project which is a proposed 5.5 Mtpa longwall with a mine life of at least 20 years.

New Hope Corporation: The Jeebropilly mine recommenced in mid-2008 and is expected to have a capacity of 800 000 tonnes per annum (tpa) by late 2009. The $36 million expansion of New Acland open-cut is planned to increase production from 4.2 to 4.8 Mtpa in 2010.

Northern Energy Corporation: The $35 million Maryborough Project is planned to commence in late 2009. The 200 000 tpa Colton open-cut mine is expected to export coking coal using the Port of Bundaberg over an initial five year mine life. The $600 million Elimatta Project in the Surat Basin is planned to start in 2012 with an open-cut production of 4 Mtpa over an initial 20 year mine life.

Tarong Energy: Since January 2008 the Meandu open-cut mine has been operated by Tarong Energy. The new $500 million Kunioon mine is planned to replace the depleted Meandu mine in 2011. The proposed 7 Mtpa Kunioon open-cut mine will be connected to Tarong's two power stations by a 16 km conveyor.

Caledon Resources plc: By January 2008 the Cook Colliery had installed the new continuous bolter-miner equipment with a Magatar continuous haulage system. Caledon plans to increase production from 500 000 tpa to 1.1 Mtpa.

Lake Vermont Resources Pty Ltd: Open-cut mining at the $176 million 4 Mtpa Lake Vermont project commenced in 2008.

Waratah Coal: The $5.3 billion China First Project located 35 km north of Alpha in Central Qld is planned to produce 25 Mtpa of open-cut thermal coal from 2013. Infrastructure includes a 474 km rail line to the Abbot Point State Development Area.

Hancock Prospecting: The $7.5 billion Alpha Project is planned to produce 40 Mtpa of open-cut thermal coal commencing in 2013. Hancock plans to build 500 km of railway and a new port at either Abbot Point or Dudgeon Point near Hay Point.

Coal loading at Newlands mine, Queensland (Xstrata plc)

Cockatoo Coal: In December 2008, the company completed a $52.5 million acquisition of a 62.5% interest in the Baralaba coal mine from Peabody Pacific. Cockatoo plans to increase production from 300 000 tpa to 0.42 Mtpa. Cockatoo Coal is undertaking a pre-feasibility study on a 3 Mtpa open-cut thermal coal mine at the Woori deposit in the Surat Basin.

Syntech Resources Pty Ltd: Construction of the $250 million Cameby Downs open-cut mine is expected to commence in July 2009. Production of 1.4 Mtpa of thermal coal is planned to start in 2010 with exports through the Port of Brisbane.

Linc Energy: In April 2009 the demonstration gas-to-liquids plant at the Chinchilla Underground Coal Gasification project was officially opened.

Carbon Energy: The $20 million Underground Coal Gasification trial at Bloodwood Creek was completed in early 2009.

Cougar Energy: Plan to trial Underground Coal Gasification near Kingaroy during 2009. Cougar propose to build a $500 million 400 megawatt power station.

NEW SOUTH WALES

BHP Billiton: At the Mt Arthur project an investigation is underway into the introduction of a $300 million underground punch longwall into the Woodlands Hill seam with a capacity of up to 8 Mtpa commencing in 2011. In January 2009 the NSW Department of Planning gave approval for the Dendrobium Colliery to extend the mine life to 2030.

Coal and Allied: (CA) (75% Rio Tinto): At the Bengalla mine CA is spending $25 million in 2009 to upgrade the coal handling and preparation plant. In 2008 CA completed a feasibility study on the $1.3 billion Mount Pleasant project near Muswellbrook. The 8 Mtpa open-cut thermal coal mine is expected to start in 2013.

Xstrata Coal: In February 2008 Xstrata paid US$903 million to acquire the Newpac No1 underground longwall mine from Resource Pacific Holdings Ltd. In March 2008 the $290 million Glendell mine commenced operations with a production capacity of 4.5 Mtpa. The Liddell expansion was completed in late 2008 with capacity increasing from 4.5 to 7 Mtpa. At Bulga production from the Beltana

longwall is expected to be replaced by production from the $350 million Blakefield South longwall in 2010. The $1.1 billion Mangoola open-cut project commenced development in August 2008 and is expected to produce up to 10.5 Mtpa of thermal coal.

Anglo Coal: In February 2008 the NSW Government approved the $35 million extension to the Drayton open-cut mine which will increase production from 5.5 to 8 Mtpa and extend the mine life until 2017.

Centennial Coal: Construction of the $100 million Airly Colliery began in early 2009 with the first coal expected in 2010. This continuous miner operation will produce up to 1.8 Mtpa of thermal coal for both export and domestic use. At Angus Place, a new longwall commenced operation in July 2008. At the Charbon Colliery, Centennial is seeking development consent to mine the remaining reserves. At the Mandalong Colliery construction commenced in April 2009 on facilities which will allow exports of up to 1 Mtpa.

Peabody Pacific Pty Ltd: In mid-2008, a $50 million expansion of the Wambo wash plant was completed. The Metropolitan Colliery is seeking approval for a $50 million expansion to extend the mine life by 23 years until 2034 and to double the coal production to 3 Mtpa.

Gloucester Coal: At the Stratford wash plant a product stockpile expansion is expected to be completed in mid-2009. Gloucester is seeking approval to extend to Duralie operation beyond 2011.

Felix Resources: In late 2008 construction commenced at the $405 million Moolarben project. The 10 Mtpa thermal coal project is expected to start shipping coal in 2010. After the open-cut has reached full capacity an underground longwall operation is planned to be installed at the mine.

Gujarat NRE Resources: Development commenced at the NRE Wongawilli Colliery in February 2008. Gujarat plans to spend $65 million over two years to increase production to 2.5 Mtpa in 2010-11. The Wonga Mains Project at the NRE No1 Colliery commenced in January 2008. The project involves driving three roadways into the Illawarra escarpment at Russel Vale to access to the Wongawilli coal seam.

Yancoal Australia Pty Ltd: The $80 million Stage 3 Austar Longwall Top Coal Caving (LTCC) mine extension project is expected to start extracting coal in 2010.

Donaldson Coal Pty Ltd: The $84 million Abel bord and pillar mine commenced operation in March 2008 with a production capacity of 4.5 Mtpa over a 21 year mine life. Coal will be trucked to the existing Bloomfield coal processing plant.

Whitehaven Coal Mining Ltd: The $140 million, Stage 1 Narrabri project consists of a 2.5 Mtpa bord and pillar operation which is expected to commence in late 2009. The $90 million, Stage 2 project consists of a 7 Mtpa longwall planned to commence in 2011. The $15 million 1 Mtpa Sunnyside open-cut mine started production in December 2008. The $35 million Rocglen open-cut commenced operation in late 2008 at a rate of 1.5 Mtpa.

Wyong Areas Coal Joint Venture (Kores Australia 82.25%): The $550 million Wallarah 2 Coal Project is planned to produce 4 to 5 Mtpa of export quality thermal coal over a 40 year period.

Coalworks Ltd: At the Oaklands North Project near Jerilderie a 3 Mtpa open-cut mine is proposed to export thermal coal.

Coalpac Pty Ltd: In January 2009 the NSW Department of Planning approved a $4 million expansion of the Invincible mine from 500 000 tpa to 0.9 Mtpa which will increase the mine life to 8 years.

WESTERN AUSTRALIA AND SOUTH AUSTRALIA

Aviva Corporation Ltd: The proposed $1 billion 400 megawatt (MW) Coolimba Power Station will use 2.4 Mtpa of coal from the Central West deposit in WA. Aviva plans to incorporate carbon capture and sequestration technologies into the project.

The Griffin Group: Griffin Coal plan to develop the $20 million Ewington 1 coal deposit about 2 km east of Collie in WA. The proposed 3.4 Mtpa mine is expected to start operating in 2009

Perdaman Chemicals and Fertilisers: Perdaman is proposing to construct a $3.5 billion fertiliser plant at Collie using 2.7 Mtpa of coal and gasification technology. The project is planned to produce 2 Mtpa of urea starting from 2013.

Babcock and Brown Power: At the Leigh Creek mine in SA Babcock and Brown Power is investigating extending the life of the open-cut beyond 2018.

Altona Resources plc: At the Wintinna coal deposit in SA Altona plans to develop a US$3 billion, 10 million barrels per annum coal-to-liquids plant with a 1140 MW power station.

INFRASTRUCTURE

Abbott Point Coal Terminal: The $95 million expansion from 21 to 25 Mtpa is due to be completed in 2009. The $818 million, Stage 3 expansion of the terminal from 25 to 50 Mtpa is planned to be completed in 2010.

Dalrymple Bay Coal Terminal: The $590 million Stage 1 expansion from 60 to 68 Mtpa was completed in March 2008. The $341.7 million Stage 2 expansion from 68 to 72 Mtpa was completed in December 2008. The $419 million expansion from 72 to 85 Mtpa is expected to be completed in June 2009.

Hay Point Coal Terminal: BMA Coal is considering the potential for expansion beyond the current 44 Mtpa.

Port of Gladstone: The $4 billion Wiggins Island Coal Terminal is planned to be developed in three stages with the initial capacity of 25 Mtpa due to be completed in 2012. Full capacity is expected to be 90 Mtpa.

Port of Brisbane: A $65 million expansion of the port is due to be completed in 2010, increasing capacity from 7 to 10 Mtpa.

Port Alma: Xstrata has commenced a $4 million pre-feasibility study into a $1 billion coal terminal at Port Alma with a capacity of up to 30 Mtpa.

Port of Newcastle: The $458 million Kooragang Island Coal Terminal expansion from 102 to 113 Mtpa is expected to be completed in late 2009. Construction commenced in January 2008 on the $1 billion Newcastle Coal Infrastructure Group's (NCIG) Coal Terminal. The Terminal will have an initial capacity
of 30 Mtpa and is due for completion in 2010.

Queensland Rail: The 69 km Northern Missing Link Rail Project between the Goonyella and Newlands
rail systems is expected to be completed in 2010. The proposed $1 billion 207 km Southern Missing Link Rail Project between Wandoan and Theodore is planned to be completed in 2011.

Australian Rail and Track Corporation: The Hunter Valley rail network is planned to be expanded to 120 Mtpa in 2009 and 150 Mtpa by 2011 at a cost of $207 million.

RESEARCH AND DEVELOPMENT

CSEnergy: Work on the $206 million Callide Oxyfuel Project commenced in November 2008. The 120 MW Callide A power station is being retrofitted with oxyfuel combustion technology.

Delta Electricity and CSIRO: A $5 million post carbon capture pilot facility was commissioned at the Munmorah power station in mid-2008. The facility will use ammonia absorption technology and the program is expected to be completed in 2009. The pilot facility will determine whether a larger $150 million demonstration plant should proceed.

ZeroGen Pty Ltd: A 120 MW Integrated Gasification Combined Cycle demonstration plant is planned to be built at Stanwell in Central Queensland.

Commonwealth Government: In September 2008 the $100 million Global Carbon Capture and Storage Institute initiative was announced. The Institute aims to facilitate carbon projects and identify and support research.

Tarong Energy and CSIRO: A $5 million post combustion CO_2 capture pilot plant is planned to be installed at the Tarong Power Station.

Brown Coal

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Brown coal or lignite is brownish-black in colour and has a high moisture content of up to 66%. Brown coal deposits occur in all Australian States with a substantial world class deposit in the Gippsland Basin of Victoria. Currently, brown coal is mined in Victoria only and is used mainly as a feedstock for power stations in the Latrobe Valley. **Energy Brix Australia** produces briquettes for industrial and domestic heating and **Australian Char Pty Ltd** produces low ash and low sulphur char products. A brown coal fertiliser product is produced at the Maddingley mine.

Resources

Recoverable economic demonstrated resources (EDR) for 2008 was 37.2 Gigatonnes (Gt) which was slightly less than in 2007 as a result of production losses. Recoverable paramarginal demonstrated resources (PDR) decreased about 0.5% to 38.8 Gt because of reassessment by **Blackham Resources** of the Scaddan deposit. Subeconomic demonstrated resources (SDR) remained unchanged at 16.3 Gt. Recoverable inferred resources increased about 0.2% to 101.1 Gt following the reassessment at the Scaddan deposit. Victoria accounts for 96% of Australia's identified resources of brown coal. All EDR is located in Victoria and about 93% of the total EDR is located in the Latrobe Valley.

Accessible EDR

Approximately 86% of brown coal EDR is accessible. Quarantined resources include the APM Mill site, which had a 50 year mining ban applied in 1980. Other quarantined resources include the coal under the Morwell township and the Holey Plains State Park. The resource life of the accessible EDR of 32.2 Gt is about 490 years.

JORC Reserves

No brown coal resources are JORC Code compliant. However, Geoscience Australia estimated reserves at the operating mines from published information to be about 4.8 Gt. The resource life of published reserves is estimated to be about 70 years.

Exploration

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

Production

Australian brown coal production for 2007-08 was 66 million tonnes (Mt), all from Victoria. The Latrobe Valley mines of Yallourn, Hazelwood and Loy Yang produce about 98% of Australia's brown coal. Locally significant brown coal operations occur at Anglesea and Maddingley.

World Ranking

Australia has about 25% of world recoverable brown coal EDR and is ranked first. Australia produces about 8% of the world's brown coal and is ranked as the fifth largest producer after Germany (20%), China (11%), the USA (9%), Russia (9%) and Greece (8%).

Industry Developments

Environmental Clean Technologies Ltd: Construction of a 150 kilotonnes per annum (ktpa) Coldry commercial demonstration plant is due to commence in 2009 in the La Trobe Valley. The Coldry process is a low pressure technology which expels 95% of the water from brown coal to produce a dense high energy pellet.

Loy Yang Power: A $6.3 million Mechanical Thermal Expression (MTE) pilot plant was tested in 2007-08. The MTE process allows more than 70% of the water in brown coal to be removed with the potential to significantly reduce carbon dioxide (CO_2) emissions when the dry coal is burnt to generate electricity. In January 2008, Loy Yang Power signed an agreement with **EESTech Inc** to undertake a feasibility study into carbon capture at the Loy Yang power station.

LaTrobe Lignite Developments Pty Ltd (LLD): A 25 tonne per hour test and development plant is planned to be constructed to demonstrate a brown coal densification technology that removes water to produce a low moisture coal.

HRL Ltd and Harbin Power Equipment Group Corporation: The partners plan to construct a 400 megawatt (MW) integrated drying gasification combined cycle power station in the La Trobe Valley. The $750 million project is expected to start operating in 2012.

Monash Energy: In December 2008, the Shell Group and Anglo American postponed the proposed $5 billion coal to liquids project in the Latrobe Valley.

International Power plc: The $370 million Hazelwood 2030 Project envisages retrofitting low emission technology to the Hazelwood power station in the Latrobe Valley. Developments include demonstration of a **RWE Energy AG** technology which uses a fine grained fluidised bed drier with an integrated waste heat recovery system to reduce water content from 60% to 12%. The Hazelwood 2030 project also involves the construction of a 25 tonne per day pilot carbon capture plant with chemical sequestering of the carbon. BioMax fuel trials in which some carbon dioxide is converted into biodiesel and ethanol using algae are continuing at Hazelwood

Exergen Pty Ltd: A continuous hydrothermal dewatering technology which removes moisture and contaminants from brown coal was trialled at a pilot plant at Beaconsfield in Tasmania.

Victorian Government: In May 2008, the Victorian Government committed $127.4 million to clean coal development. The commitment includes $110 million to establish a carbon capture and sequestration demonstration project, $5.2 million to investigate carbon storage sites in the Gippsland Basin and $12.2 million to establish Clean Coal Victoria.

Australian Energy Company: In June 2008, the company announced a $2 billion project for the Latrobe Valley to convert brown coal into urea. From 2012 about 1.2 Mtpa of urea fertiliser is expected to be produced along with 135 MW's of electricity.

Spitfire Oil Ltd: A 3.5 Mtpa open-cut mine at Salmon Gums in Western Australia is planned to be developed to provide feed to a coal-to-liquids plant producing about 7.3 million barrels of oil and distillate per annum mainly for the Kalgoorlie market.

Hybrid Energy Australia: A feasibility study is being conducted into a coal to liquids plant located at Kingston in South Australia. The FuturGas Project plans to use about 3.2 Mtpa of open-cut coal to produce 3.7 barrels of synthetic fuel per annum and 40 MW of low emission electricity.

Coal Bed Methane

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Coal Bed Methane (CBM) is a naturally occurring methane gas which is formed during the coalification process (when organic matter is converted into coal). The methane is usually mixed with carbon dioxide, other hydrocarbons and nitrogen. CBM also is referred to as Coal Seam Methane (CSM) and Coal Seam Gas (CSG). Methane that is produced or released as part of coal mining operations is called Coal Mine Methane (CMM)

CBM is similar to conventional natural gas and is used to power water heaters, stoves and space heaters for both domestic and business settings as well as to fuel industrial facilities and to generate electricity. Water is produced as a by-product of CBM production although any beneficial reuse of the water depends on a number of factors including its quality, cost of treatment required and pipeline infrastructure. Water of suitable quality can be used for town water, aquaculture, recharging aquifers, wetlands, recreational lakes or at mining operations and power stations. Poor quality water may be required to be contained in storage ponds.

Resources

As at December 2008 the proven and probable (2P) reserves of CBM in Australia were 16 179 Petajoules (PJ) a 116% increase over the 2007 2P reserves of 7 500 PJ. The life of the resource is more than 115 years at the current rate of extraction of 138.5 PJ. Queensland has 15 302 PJ (or 94.6%) of the 2P reserves with the remaining 877 PJ in New South Wales. Note that there are no CMM reserves.

Exploration expenditure

Data relating to exploration expenditure are not published by ABS on either a state or national basis. During 2007-08 CBM exploration in Queensland continued at record levels with about 600 CBM wells drilled compared to 70 natural gas wells. Exploration in Queensland continues to concentrate on the Bowen, Galilee and Surat Basins while in New South Wales exploration continues in the Sydney, Gunnedah, Gloucester and Clarence-Moreton Basins which all have 2P reserves. Other prospective basins include the Pedirka, Murray, Perth, Ipswich, Maryborough, and Otway.

Production

In Australia, production of CBM was zero in 1995 and 20 PJ in 2003. In 2008 CBM production has risen to 138.5 PJ which is a 26% increase on the 2007 production of 110 PJ. In 2008, Queensland produced 133.2 PJ (or 96%) from the Bowen and Surat Basins. In New South Wales 5.3 PJ was produced from the Sydney Basin. Total conventional gas production in Queensland during 2008 was 89.8 PJ. In other words CBM provided 60% of Queensland gas needs during 2008. According to the independent industry commentator, Wood Mackenzie, CBM could provide up to 50% of the Australian east coast natural gas supply by 2020. Note that CMM is not counted in CBM production statistics.

Industry developments

QUEENSLAND

Queensland CBM and CMM developments include:

Energy Developments Ltd: In late 2008 the A$60 million 40 Megawatt (MW) CMM power plant commenced operating at the Moranbah North Colliery.

Liquefied Natural Gas Ltd: In February 2008 the company announced that Norwegian group **Golar LNG Ltd** would take a 40% stake with an off-take agreement in a A$1.5 billion 1.5 million tonnes per annum (Mtpa) Gladstone liquid natural gas (LNG) plant which is planned to begin operating in 2012. Arrow Energy has agreed to supply the required CBM to the LNG plant in Gladstone.

Arrow Energy: In June 2008 Shell agreed to take a 30% stake in Arrow Energy's CBM licences in Queensland. Arrow Energy is planning to build an initial 1.5 Mtpa LNG plant at Fisherman's Landing near Gladstone with production starting in 2012. Royal Dutch Shell is investigating a site on Curtis Island near Gladstone for an LNG plant. In October 2008 Arrow Energy was given approval to develop the Stratheden production lease 20 km north west of Dalby in the Surat basin. Arrow and ERM Power plan to jointly develop the A$545 million 450 MW Braemar 2 power station 40 km south west of Dalby. In late 2008 Arrow Energy and the Dalby Town Council initiated a A$16 million program to upgrade a reverse osmosis plant at Dalby. After the upgrade Arrow Energy will supply up to 5 million litres of water a day for treatment which can then be made available to supplement town water.

Origin Energy: In September 2008 **ConocoPhillips** and Origin formed a joint venture to commercialise Origin's CBM reserves. The partners plan to develop four LNG plants at Gladstone with production from the first two 3.5 Mtpa plants expected in 2014. In late 2009, Origin is expecting to commission a A$780 million 630 MW gas fired power station on the Darling Downs using CBM from Spring Gully.

Santos Ltd: In May 2008 the Malaysian Government owned **Petronas** bought a 40% stake in Santos's Gladstone LNG project. The partners plan to build a A$5 to A$7 billion LNG project at Gladstone with a capacity of 3 to 4 Mtpa commencing in 2014.

Queensland Gas Company: The company was taken over by the British owned **BG Group** in December 2008. Queensland Gas plans to build an A$8 billion LNG plant in Gladstone with a capacity of 3 to 4 Mtpa commencing in 2013. The 135 MW CBM fired Condamine power station is due to be commissioned in 2009. The company currently has the capacity to produce about 17 megalitres of water a day and is negotiating an agreement with the Dalby Regional Council to supply half a billion litres a year to the town of Miles.

Sunshine Gas: The company was taken over by Queensland Gas Company in August 2008. Sunshine Gas and **Sojitz Corporation** had planned to build a A$570 million 500 000 tpa LNG plant at Gladstone using Lacerta CBM with first production in 2012.

Pure Energy Ltd: In February the company upgraded the Cameron Project 2P reserves from 394 to 522 PJ.

Bow Energy Ltd: In March 2009 the company announced 192 PJ of 3P reserves at the **Don Juan Project** in the Surat Basin

Queensland Government: In July 2008 the Queensland Government announced a A$5 million grant for a feasibility study into the use of water produced from CBM extraction.

NEW SOUTH WALES

CBM and CMM developments include:

Coal and Allied Ltd: In November 2008, the company announced a A$5 million trial to extract CBM prior to open-cut mining at the Mt Thorley Warkworth mine in the Hunter Valley.

Metgasco Ltd: The company plans to build the 30 MW gas fired Richmond Valley power station to be fuelled by CBM over 15 years. Metgasco also plans to provide CS Energy's Swanbank Power Station in Ipswich with 18 PJ/ annum of CBM via the Lions way pipeline.

Sydney Gas: In November 2008, Sydney Gas announced a A$30 million well drilling program at Camden. In December 2008 AGL made a takeover offer for Sydney Gas. AGL, the operator of the Camden gas project, received approval to construct and operate four wells at Spring Farm and sixteen at Menangle Park.

Eastern Star Gas: The company plans to construct a 32 km pipeline from the **Narrabri Coal Seam Gas Project** to the existing Wilga Park power station which is planned to be expanded from 12 to 40 MW. Eastern Star Gas is considering constructing an LNG plant at Newcastle.

Macquarie Generation: The company is proposing to construct 75 km of pipelines from local underground coal mines to supply methane gas as a supplementary fuel to the Liddell Power Station in the Hunter Valley.

Coal to Liquids

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The production of liquids from coal requires the breakdown of the chemical structures present in coal with the simultaneous elimination of oxygen, nitrogen and sulphur and the introduction of hydrogen to produce a stable liquid product. Coal can be converted into a variety of products including petrol, diesel, jet fuel, plastics, gas, ammonia, synthetic rubber, naptha, tars, alcohols and methanol.

There has been extensive research into converting coal to a liquid but basically there are three approaches, pyrolysis (direct method), hydrogenation (direct method) and gasification and synthesis (indirect method).

CTL technology was developed in the early 20th century and was used in Germany in the 1930s and 1940s. Since 1955 in South Africa, **SASOL** has operated a CTL plant and in late 2008 the **Shenhua Group** commissioned a CTL plant at Ordos in China. In Australia from 1955 to 1969 a Lurgi gasification plant produced gas for the Melbourne market from briquetted Yallourn brown coal. From 1985 to 1990 a Japanese consortium operated a CTL pilot plant at Morwell which demonstrated that hydrogenation of La Trobe Valley brown coal was technically feasible.

Synthetic gas (syngas) can be produced also by underground or in-situ coal gasification. In this method fuel gases are produced underground when a coal seam gets sufficient air to burn but insufficient for all consumable products to be consumed. Carbon dioxide, carbon monoxide, hydrogen and methane are produced to yield a gas of low, but variable heat content. Air is pumped into the burning coal bed through a well and the gas is drawn off through another well from a point behind the "fire-front". The gasified coal can then be used to produce liquid fuels (or electricity). The power station at Angren in Uzbekistan has the only operating underground coal gasification project in the world. At present, many projects are in various stages of development in Australia, the USA, Canada, South Africa, India, Vietnam, New Zealand and China to produce electricity, liquid fuels and syngas. A problem associated with this form of extraction is the collapse of the coal bed and surface subsidence.

Resources

In Australia in 2008 no CTL projects were considered economically viable given that there are only two operating projects in the world and those in Australia are in the demonstration phase of development. Because CTL technology is well established, the CTL resource of 16.3 billion barrels is considered a paramarginal demonstrated resource. Operating mines were not included except at New Acland where the **New Hope Corporation** plans to develop CTL alongside its conventional coal operation. If CTL projects ever become viable in Australia the resource life at current rates of oil consumption is about 50 years. At present, the location of coal which has been considered suitable and available for CTL conversion includes coals from the Surat, Clarence-Moreton, Oaklands and Gippsland Basins.

Industry Developments

New Hope Corporation: The company is considering constructing a CTL pilot plant near the New Acland mine in Queensland which would process some 185 000 tonnes per annum (tpa) of coal into 75 million litres of fuel.

Altona Resources plc: A 10 million barrels a year CTL plant and 1140 MW power plant is proposed to be constructed near the Wintinna coal deposit in South Australia. The project would cost about US$3.0 billion and require a 10 million tonnes per annum (Mtpa) open-cut mine.

Ambre Energy Ltd: Ambre plans to demonstrate coal gasification technology at the Felton coal deposit in Queensland. If successful Ambre proposes to expand the plant to process 3.8 Mtpa of open-cut coal for an annual production of 0.8 Mtpa of dimethyl ether and 200 Megawatts (MW) of electricity.

Monash Energy: In December 2008 the proposed Monash Energy project in Victoria was postponed. The project was planned to include a A$300 to A$400 million brown coal to liquids demonstration plant and, if viable, a A$5 billion 60 000 barrels per day CTL operation was planned to be built.

Spitfire Oil Ltd: A 3.5 Mtpa open-cut mine at Salmon Gums in Western Australia is planned to be developed to provide feed to a brown coal to liquids plant producing about 7.3 million barrels of oil and distillate per annum, mainly for the Kalgoorlie market.

Blackham Resources Ltd: Blackham propose to develop a CTL operation at the Scaddan brown coal deposit in Western Australia. Based on 30 000 barrels of fuel per day the operation could provide feedstock for 40 years.

Hybrid Energy Australia: A feasibility study is being conducted into a CTL plant located at Kingston in South Australia. The FuturGas Project plans to use about 3.2 Mtpa of open-cut brown coal to produce 3.7 barrels of synthetic fuel per annum and 40 MW of low emission electricity.

Syngas Ltd: Plan to produce 15 000 to 30 000 barrels of diesel per day from an open-cut mine at the Clinton brown coal deposit in South Australia.

Underground Coal Gasification

Linc Energy: In June 2008 Linc Energy and **SAPEX** merged to develop potential coal resources in South Australia's Arckaringa Basin using Linc's underground coal gasification technology. In October 2008, the first diesel was produced from the Chinchilla project in Queensland. In April 2009, the demonstration gas-to-liquids plant at the Chinchilla Underground Coal Gasification project was officially opened.

Carbon Energy: In October 2008, construction of surface facilities was completed for an Underground Coal Gasification trial at Bloodwood Creek in Queensland. In January 2009, trial syngas production commenced.

Cougar Energy: The company plans to trial underground coal gasification near Kingaroy in Queensland during 2009. Cougar propose to build a A$500 million 400 MW power station.

Copper

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Australia is a major copper (Cu) producer with mining and smelting operations at Olympic Dam in South Australia (SA) and Mount Isa in Queensland (Qld). Other significant copper producing operations are at Northparkes, Cadia-Ridgeway and Tritton in New South Wales (NSW), Ernest Henry and Osborne (Qld), Nifty and Golden Grove in Western Australia (WA), and Mount Lyell in Tasmania (Tas). Copper and copper alloys are used in building construction, electrical cables and electrical equipment as well as in industrial machinery and equipment. An average car contains over 20 kilograms (kg) of copper and suburban homes now have around 200 kg of copper.

Resources

Australia's total demonstrated resources of copper rose by 13 million tonnes (Mt) in 2008 to 120 Mt. The increase occurred mostly in SA, NSW and Qld.

Australia's Economic Demonstrated Resources (EDR) of copper rose by 18.4 Mt to 77.8 Mt, an increase of 31% for the year. South Australia has the largest EDR at 57 Mt, which increased by 32% in 2008 to be around 73% of the national total. Almost all of the SA EDR are associated with the Olympic Dam deposit, where, with the release of new data in 2008, EDR rose by 13.1 Mt to 54.9 Mt. Queensland has the second largest EDR with 11% of the national total, followed by NSW (9%) and WA with (6%).

Inferred Resources fell by 11% to 34.2 Mt in 2008 largely as a result of the conversion of Inferred Resources to Indicated Resource at Olympic Dam. South Australia holds 58% of Australia's Inferred Resources (mostly at Olympic Dam) followed by Qld 18%, WA 10% and NSW 9%.

Accessible EDR

All copper EDR is accessible.

JORC Reserves

JORC Code reserves account for around 25% of Accessible Economic Demonstrated Resources (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. The copper resource life using national EDR divided by annual production is 87 years, but using the ore reserve and dividing by annual production gives a resource life of only 22 years.

Exploration

Spending on exploration for copper rose by 11% in 2008 to $293 million. Expenditure in Qld of $108 million was 37% of all copper exploration. Expenditure in SA of $106 million represented a further 36%. The main areas of expenditure in Qld were the Mount Isa and Cloncurry districts. In SA expenditure was at the Olympic Dam deposit and in the search for further Olympic Dam style mineralisation in the Gawler Craton. Western Australia had 14% of spending on copper exploration across a range of projects and NSW had 9%, with the remainder to a lesser extent in the Northern Territory (NT) with 3% and Tas with 1%. Expenditure on exploration for copper made up 11% of all mineral exploration.

Production

In 2008, Australia's mine production of copper totalled 887 kilotonnes (kt) of contained copper, 2% higher than 2007 (871 kt). Queensland continued to dominate production with 389 kt, largely from the Mount Isa region. This was 3% more than in 2007 and represented 44% of Australian production, slightly up from 43% in 2007. South Australia held the second largest producer position with an increase of 10% to 196 kt. Olympic Dam produced all of SA's output, contributing 22% of national production. New South Wales produced 146 kt in 2008, 13% less than in 2007 and largely from Cadia-Ridgeway, Northparkes and Tritton. Western Australia produced 126 kt, up 7% and largely from Nifty and Golden Grove. Tasmania produced 28 kt, down 8% and nearly all from Mount Lyell.

The value of Australia's exports of copper concentrates and refined copper in 2008 totalled just under $6.7 billion, up slightly on the $6.4 billion in 2007 but down from 4% to 3% of the value of total merchandise exports. Australian dollar copper prices decreased for a second year in 2008 after three prior years of substantial rises. The average copper price was down 6% in 2008 to $7,975 a tonne compared to the average of $8,512 a tonne in 2007. Exports in 2008 increased 15% to 811 kt despite only slightly increased copper production.

World Ranking

Based on United States Geological Survey (USGS) data for other countries, Australia has the second largest EDR of copper (13%) after Chile (27%) and ahead of Peru (10%), Mexico, Indonesia and the United States of America (USA) with 6% each and China and Poland with 5% each. As a producer, Australia ranks fifth in the world, with 6% of world copper production, after Chile (36%), the USA and Peru (both 8%) and China (also 6%).

Industry Developments

Olympic Dam (SA): Production for 2008 totalled 196 kt of copper cathode. This was 10% more than in 2008 but 17% below the nameplate capacity of 235 kilotonnes per annum (ktpa). BHP Billiton has undertaken a two-year pre-feasibility study to examine capacity expansion options. If the expansion proceeds, it is likely to see the advent of an open pit mine which would operate simultaneously with the existing underground mine and lift ore production six-fold. The project would increase copper production to 750 ktpa, with Olympic Dam becoming one of the world's largest mines. This will require major infrastructure for water, energy, and transport as well as a township expansion. The existing smelter would be expanded to produce 350 ktpa of the copper. A new concentrator and new hydrometallurgical plants would lift concentrate production four-fold and generate a surplus 1.6 million tonnes per annum (Mtpa) of copper concentrate for smelting overseas. BHP Billiton is seeking approval from the Australian government and the SA and NT governments for the expansion. As part of the process, a detailed Draft Environmental Impact Statement (EIS) has been prepared to comply with the guidelines set by the three governments. The proposed expansion would be a progressive development, requiring construction activity over a period of 11 years.

BHP Billiton reported an increase in the Olympic Dam resource base of 635 Mt (8%) for the year ended 30 June 2008 to 8490 Mt of ore. The total sulphide resource base is now 8339 Mt at 0.88% Cu, 0.28 kilograms per tonne (kg/t) uranium (U_3O_8), 0.31 grams per tonne (g/t) of gold (Au) and 1.5g/t of silver (Ag). The increase was due to drilling of a further 487 surface and underground holes totalling 192 000m. This has provided greater confidence in the continuity of mineralisation and has resulted in the conversion of resource material from Indicated Resource to Measured Resource and from Inferred Resource to Indicated Resource. Also, 600 Mt of new Inferred Resource was added. A 40% increase in overall ore reserves is due to additional resource material being available for conversion to Proven and Probable Reserves. In addition, mining parameters for stope design and grade factors have been updated following a review of the previous two years reconciliation data. Total Reserves are now 473 Mt at 1.86% Cu, 0.60 kg/t U_3O_8, 0.76 g/t Au and 3.95 g/t Ag.

Mt Isa and Ernest Henry (Qld): Copper-in-concentrate production in 2008 from Xstrata Plc's Mount Isa and Ernest Henry operations totalled 263 kt, a decrease of 2% compared to 2007 resulting from planned lower head grades at Mount Isa, which was offset partially by higher milled tonnes and grades at Ernest Henry. The decrease at Mount Isa was 12% to 152 kt, while the increase at Ernest Henry was 16% to 111 kt. The last phase of the copper smelter expansion project at Mount Isa, namely the construction and commissioning of two new oxygen plants, was completed in the fourth quarter of 2008, raising the nominal production capacity to the targeted 300 ktpa. This project delivered improved smelter production in the second half with total 2008 anode production up by 8% to 236 kt. At the Townsville refinery, this Mount Isa smelter anode, together with anode purchased from Xstrata Copper's Altonorte smelter in Chile, resulted in an increase of 15% in copper cathode production to 267 kt compared to 2007.

During 2008, studies advanced into underground mass mining options for both the Mount Isa and Ernest Henry mines. At Ernest Henry, more than 50 000m of drilling was completed and used to update the mineral resource model. This resulted in a 19% increase for the Ernest Henry underground mineral resources to 56 Mt, including an initial underground Ore Reserve estimate of 10 Mt at 1.1% Cu and 0.6 g/t Au. The feasibility study into a potential large scale underground sub-level caving operation at Ernest Henry is expected to be completed in the first half of 2009. A feasibility study evaluating further emissions capture enhancements at the Mount Isa copper smelter is continuing.

Prominent Hill (SA): Development and construction of OZ Minerals' copper and gold mining operation at Prominent Hill was 97% complete as at 31 December 2008 and final work was completed early in 2009. The first copper gold concentrate was delivered on 26 February 2009. The company has forecast 2009 production of as much as 100 kt of copper and 70 000 ounces of gold in concentrates. The operation comprises an open pit mine, a conventional grinding and flotation processing plant with 8 Mtpa capacity, a permanent village, haulage road, power line and bore field. Prominent Hill concentrates travel directly to customers, including smelters in China and India, via the Adelaide to Darwin railway and the Port of Darwin. The open-pit mine was estimated to operate for 10 years. However, exploration drilling has continued to increase resources both deeper and laterally and a new deposit has been identified immediately to the west of the mine. In September 2008 OZ Minerals announced that total contained copper had increased a further 35% to 2.5 Mt and contained gold was up by 100% to 7.4 million ounces (Moz). Studies of underground mining and expansion could result in the mine life extending to 2030.

Cadia-Ridgeway (NSW): During the year Newcrest Mining Limited reported a significant increase in the Cadia Valley Mineral Resource of 8.3 Moz of gold and 2.4 Mt of copper. Total Cadia Valley contained metal is now 39.4 Moz gold and 7 Mt copper in 2479 Mt of ore. Most is at Cadia East which has a total resource of 1834 Mt at 0.5g/t Au and 0.3% Cu. Copper production was 26 kt for Cadia and 34 kt for Ridgeway for the 12 months to 30 June 2008. The Ridgeway Deeps underground project at Cadia continues on schedule and within budget with production expected to commence on schedule in 2010. Decline development for the Cadia East project commenced in May 2005 and by the end of the pre-feasibility phase in December 2008 the target depth of 955m below the surface was reached on schedule and within budget. A new approach to developing and mining at Cadia

East has been recognised. Study work has established that development of an underground mine in the upper portion of the Cadia East ore body - previously planned to be mined as an open pit - will negate the need for significant pre-stripping and will increase metal production rates. Newcrest has reported that Cadia East's panel cave will be Australia's largest underground mine and have an expected life of more than 30 years.

Northparkes (NSW): Production for 2008 was 25 kt of contained copper, which was down from 43 kt in 2007 and 83 kt in 2006. Rio Tinto Ltd reported production was constrained throughout 2008 as a result of the early closure of the E26 Lift 2 block cave in 2007 because of the ingress of clay in the underground draw points. Surface stockpiles were used to maintain full mill capacity while additional underground and open cut ore sources were brought into production. This included construction of the Lift 2 North extension, which was completed in early 2008 and ramped up to full production in mid-2008, and the E22 pit, which was re-opened and began producing ore from July 2008. The $270 million E48 block cave project, approved in November 2006 and expected to extend mine life until 2016, was suspended in January 2009 when 75% complete until prices for copper recover. Exploration drilling has identified mineralisation beneath the E48 project with the potential to sustain larger scale underground mining. A near doubling of reserves at Northparkes in 2008 was the result of updated models following additional drilling, technical studies, application of new economic parameters and upgrading resources to reserves.

Carrapateena (SA) and Rocklands (Qld): These two newly discovered significant copper deposits were both the subject of extensive drilling through 2008 but for both deposits the resultant resources are yet to be reported. For Carrapateena, owner RMG Services Pty Ltd and operator Teck Resources Limited have not released any resource figures since discovery in 2005 despite more than three years of appraisal drilling totalling over 75 000m. Teck has the right to acquire Carrapateena by paying 66% of the market value determined by an independent valuer. At Rocklands, owner CuDeco Limited reported in October 2008 that more than 130 000m of drilling in more than 1000 holes had been completed and new mineralisation had been discovered. It said further extensive drilling was planned. The last resources for Rocklands date from August 2006 when CuDeco announced an Inferred Resource of 25 Mt at 2% Cu equivalent.

Lady Annie, Leichhardt, Eloise and Mount Gordon (Qld): Lower copper prices, particularly in the last quarter of 2008, contributed to a number of copper mines moving to care and maintenance. These included Lady Annie, Leichhardt (Mount Watson), Eloise and Mount Gordon. CopperCo Limited officially opened operations at Lady Annie in October 2007 and production started at a rate of 19 ktpa from a resource of 40 Mt at 0.9% Cu for 359 kt of contained copper. Matrix Metals Ltd commenced mining in April 2007 of 8 Mt of copper oxide ore at 1% Cu from the Mount Watson open pit for processing 30 kilometres (km) south at its refurbished Mount Cuthbert plant to produce 5 ktpa of copper cathode. In November 2008 both CopperCo and Matrix appointed voluntary administrators and then in February 2009 high rainfall led to mining being suspended and the projects were moved to care and maintenance. The Eloise underground copper mine which produced 10 kt of copper in 2008 was placed on temporary care and maintenance in December 2008. The owner, FMR Investments Pty Ltd, advised that after taking into consideration a number of factors, particularly the substantial reductions in the copper price, that the most commercial approach for managing and maximising future value was to suspend mining activities. Similarly, Aditya Birla Minerals Limited put the 22 ktpa Mount Gordon copper mine under care and maintenance in January 2009.

Mount Elliott, Mount Dore, and Starra Line (Qld): In September 2008, Ivanhoe Australia Limited released its first resource statement for the neighbouring deposits of Mount Elliott, Mount Dore and Starra Line south of Cloncurry. The three projects have a combined resource of 3.1 Mt of contained copper and 5.1 Moz of gold. The biggest deposit of the three is Mount Elliott with a 475 Mt resource at 0.5% Cu and 0.3g/t Au. Mount Dore has a resource of 80 Mt at 0.6% Cu, while Starra Line has a 30 Mt resource at 0.9% Cu and 0.8g/t Au. The company plans to move to a scoping study to evaluate mining options at Mount Elliott after an updated resource is completed early in 2009. It also plans to undertake a scoping study into installing a new 2 Mtpa concentrator at nearby Starra Line.

Diamond

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Diamond is composed of carbon and is the hardest known natural substance, although it can be shattered with a sharp blow. It also has the highest thermal conductivity at room temperature of any known material. Diamonds form 150–200 kilometres (km) below the Earth's surface at high temperatures (1050°C–1200°C) and pressures (45–55 kilobars). They are carried to the surface within kimberlite and lamproites which intrude through the earth's crust. These intrusions form narrow cylindrical bodies called pipes and only a very small proportion have significant diamond content. When pipes are eroded, liberated diamonds can accumulate in alluvial deposits and may be found far from their source because 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, mining and exploration, stone cutting and polishing, computer chip manufacture, machinery manufacture, construction and transportation services. A large proportion of industrial diamond is manufactured and it is possible to produce synthetic diamonds of gem quality.

Resources

Australia's Economic Demonstrated Resources (EDR) decreased by 6% in 2008 for both gem/near gem and industrial to 91.9 million carats (Mc) and 95.7 Mc respectively. This resulted from reduced production at the Argyle mine in Western Australia (WA).

Accessible EDR

All diamond EDR is accessible for mining.

JORC Reserves

The Joint Ore Reserve Committee (JORC) Code reserves account for almost all Accessible Economic Demonstrated Resources (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

Australian Bureau of Statistics data indicate that expenditure on exploration for diamond in Australia in 2008 was $17 million, down 6% on 2007. Exploration continues to be concentrated in WA, notably the Kimberley region, and in the Northern Territory.

Production

Australia produced 15.7 Mc of diamond in 2008, 3.6 Mc less than in 2007 and about half of what has been produced during a number of prior years. Production was almost entirely from Rio Tinto Ltd's Argyle mine, which produced 15.1 Mc and has been recognised as the world's largest supplier of diamonds accounting for one-fifth of world natural diamond production. Argyle production is mostly industrial and cheap diamonds with an average price of US$15-16 per carat. Longer term production is expected to be about 60% of Argyle's historical annual average of 34 Mc as the open pit winds down and underground production ramps up.

World Ranking

Based on United States Geological Survey (USGS) data for other countries, Australia's EDR of industrial diamond ranks third with 16% of current world total EDR after the Democratic Republic of the Congo (Kinshasa) (26%) and Botswana (22%). No detailed data are available on world resources of gem/near gem diamond, but Australian stocks are among the largest for this category.

Australia ranks as the world's fifth largest producer of diamond by weight after Russia, Botswana, Congo and Canada. As a producer of gem/near gem diamond, Australia is the fifth largest after Botswana, Russia, Canada and Angola. For industrial grade diamond, Australia is the fifth largest producer after Congo, Russia, South Africa and Botswana.

Industry Developments

Argyle (WA): At the end of 2007, the AK1 pit experienced a wall failure, which significantly reduced ore volumes from the mine. As a result, lower grade stockpiled ore was processed through the recovery plant. Diamonds recovered decreased to 15.1 Mc in 2008 from 18.7 Mc in 2007. In January 2009, Rio Tinto Ltd announced that, in response to weakening demand and prices, the Argyle underground mining project was being slowed to critical development activities by reducing the project workforce. Full production from the underground block cave mine is expected to be delayed by two years and will not take place until 2013. Rio Tinto Limited intends to operate the open pit mine through to 2011, with reduced production in the short term. Mining will continue in the southern end of the pit to extract the remaining economic ore during 2009. Subsequently, mining is expected to move to the Northern Bowl and continue until ore is available from the underground mine. Processing in the surface operations is expected to be suspended for up to three months during 2009. The extended processing plant shutdown will provide an opportunity to perform essential maintenance, training and improvement activities to ensure processing resumes at a sustainable rate.

Ellendale (WA): Gem Diamonds Ltd reported that during 2008 it achieved targets of higher tonnage throughput and reduced cash costs. Production reached 0.589 Mc in 2008, up 24% on 2007 and 8.3 million tonnes (Mt) of ore was treated. The strength of the Australian dollar relative to the US dollar and the high price of fuel impacted costs. These cost factors were reduced in the second half of 2008. However, from October 2008 diamond prices suffered a dramatic slide with rough diamond prices dropping to around 50% of prices prevailing in early 2008 and some categories experienced declines of up to 70%. Despite this, Ellendale managed to achieve an average US$185/carat for 2008 compared with US$137/carat in 2007. The Ellendale mine has two lamproite pipes on which mining has taken place to date – the Ellendale 4 and the Ellendale 9 pipes. In November 2008, production from the lower value Ellendale 4 pit was curtailed and limited to treating ore that was in stockpile or accessible for mining within the confines of the existing pit shell. Subsequently, mining operations ceased at the Ellendale 4 pipe and were placed on care and maintenance. Mining at the Ellendale 9 pipe continues. The Ellendale mine is the world's leading producer of fancy yellow diamonds. In August, the mine entered into a sales agreement with a high end US jewellery manufacturer and retailer for its entire fancy yellow production.

Gold

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Strong gold prices continued throughout 2008 and supported stronger exploration expenditure. Production fell sharply due to a number of factors but is expected to recover some of the loss in 2009. Exploration continued to generate a very large number of intersections of economic significance, justifying further work. In addition, exploration generated an increase of 867 tonnes of gold in Australia's total resource inventory.

Gold has a range of uses but the two principal applications are as an investment instrument and for 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 2008, total Australian gold resources were 867 tonnes higher than at the end of 2007. After allowing for the replacement of those resources lost to production (215 tonnes), newly delineated resources added to the national inventory totalled 1082 tonnes (34.8 million ounces (Mozs)) in 2008.

Australia's Economic Demonstrated Resources (EDR) rose by 416 tonnes (13.4 Mozs) in 2008 to 6255 tonnes and accounted for 81% of total demonstrated resources, a similar proportion to 2006 and 2007. In 2008, EDR increased in the Northern Territory and all States except Queensland and Tasmania where small reductions occurred. Although Western Australia with 2934 tonnes continued to dominate EDR, its share fell again in 2008 to 47% of the national total compared to 49% in 2007 and 54% in 2006. This reduction in share occurred despite Western Australia's EDR increasing by 84 tonnes and was due to strong growth in other States, particularly in New South Wales, South Australia and the Northern Territory.

Subeconomic demonstrated resources rose by 191 tonnes in 2008, with an increase of 206 tonnes in the paramarginal demonstrated resources category being slightly offset by a reduction of 15 tonnes in the submarginal demonstrated resources. Resources in the paramarginal category rose to 1478 tonnes with 67% of total paramarginal resources occurring in Western Australia. This share was lower than in 2007 (72%). The submarginal demonstrated resources fell by 15 tonnes to 123 tonnes, just over half of which was in Western Australia.

Following a fall in 2007, the level of inferred resources rose by 260 tonnes in 2008 to 4596 tonnes. Western Australia (41%) and South Australia (26%) dominate inferred resources.

Accessible EDR

EDR for gold are essentially unencumbered (less than 2% is in any form of restricted area). At Australia's 2008 rate of production, EDR is sufficient for about 29 years. However, the 2008 production was substantially lower than the output levels of recent years for a number of reasons which suggests that a resource life estimate based on these factors may be somewhat misleading. Resources classified only as reserves under the Joint Ore Reserve Committee (JORC) Code will support only 16 years at the 2008 production rate. These estimates are average figures and there are some operations which may continue after these periods and there are others that will close before the end of those periods. The relatively short life suggested by these estimates highlights the importance of maintaining substantial short and medium term exploration programs.

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 2008, just under 54% of EDR fell into the JORC Code reserves categories.

Exploration

On the basis of calendar year exploration spending reported by the Australian Bureau of Statistics (ABS), gold was supplanted by iron ore as the dominant single commodity target in 2008 and its share of total spending fell from 24% in 2007 to 22% in 2008. This fall occurred despite a 13% increase in exploration expenditure to $570 million. Western Australia continued to dominate gold exploration by attracting $329.1 million ($32.8 million more than in 2007). However, its share of total gold exploration fell again to 58%. All other regions, except the Australian Capital Territory, had gold exploration during the year and encouraging results were reported from each jurisdiction.

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

On a financial year basis, the ABS reported gold exploration spending for 2007-08 was $592.7 million, an increase of $136.9 million over 2006-07.

Data published by the Canadian company Metals Economics Group (MEG) on company exploration budgets for non-ferrous minerals indicates that intended budgets for gold exploration in Australia for 2008 totalled US$700.4 million (A$756 million based on the exchange rate used by MEG). This budget was about 19% higher than actual spending reported by the ABS. The differences between reported budgets and actual spending on gold exploration may have been caused in part by increased

spending on iron ore and base metals exploration resulting in gold budgets being reduced as funds were directed to these commodities. In addition, the impact of the global financial crisis toward the end of the year my have reduced some actual expenditure on gold exploration.

The MEG data show that 36% of gold exploration budgets were expected to be directed at grassroots exploration compared to 47% in 2007 although it is a similar level to the 33% in 2006. The shares of both minesite and late stage gold exploration budgets reported by MEG rose in 2008 to 25% for minesite exploration (23% in 2007) and 39% for late stage exploration (30% in 2007). These budgets highlight the continued concentration on brownfields exploration for gold.

New gold resources were reported for many deposits across the country. These included:

- At **Newcrest Mining Ltd's** Cadia Province, New South Wales, the **Cadia East** mineral resource increased by 6.6 Mozs Au and 1.88 million tonnes (Mt) Cu while its ore reserve rose by 5.0 Mozs Au and 1 Mt Cu. An initial mineral resource for **Big Cadia**, located northeast of the Ridgeway mine, was estimated at 0.44 Mozs Au and 0.17 Mt Cu.
- **Castlemaine Goldfields Ltd** announced an initial Inferred Resource of 2.1 Mt @ 8.3g/t Au for to 574 000 ounces (oz) Au for the **Chewton** deposit located adjacent to Wattle Gully mine, Victoria. There is an additional Inferred Resource of 610 000 tonnes @ 5.7 grams per tonne (g/t) Au for 112 000 oz Au in remnant areas of the adjacent Wattle Gully gold mine.

New gold mineralisation was found across the continent and at depth below known deposits in a variety of mineralisation styles. The Archean greenstones of Western Australia's Yilgarn Craton remain a very favourable target, but substantial opportunities also exist in other provinces. A major review of the highlights of gold exploration in Australia in 2008 is available in the document ***"Australian Mineral Exploration:A Review of Exploration for the Year 2008 - Extended Edition"*** available for download from the Geoscience Australia web site. Indicative of drill intersections reported from across the country in 2008 which highlight the potential, with further exploration, to yield resources to underpin the Australian gold sector into the medium to longer term were:

- At the **McPhillamys** Prospect, 35 km southeast of Orange, New South Wales, **Alkane Resources Ltd** and **Newmont Australia Ltd** reported a major gold intersection of 366 metres (m) @ 1.85g/t Au from 134m depth.
- Also in New South Wales, **Cortona Resources Ltd** announced results from drilling at the **Dargues Reef** prospect at Majors Creek where intersections included 13m @ 8.33g/t Au; 3.2m@ 15.4g/t Au and 35m @ 18.17g/t Au.
- **Dominion Mining Ltd** reported good results from it Challenger Deeps Surface Drilling Program at its **Challenger** mine in South Australia, which aimed to test the depth continuity of mineralisation. Significant intersections reported included 12.5m @ 13.84g/t Au from 997.5m depth; 4.17m @ 14.33g/t Au from 887m, and 4.00m @ 22.28g/t from 1005m.
- **Westgold Resources Ltd** advised that drilling at **Rover 1** near Tennant Creek, Northern Territory, returned significant high-grade mineralisation. Intersections included 65.75m @ 11.0g/t Au; 66m @ 4.26g/t Au, 0.56% Cu, 0.08% Co, 0.20% Bi and 2.1g/t Ag which included 9m @ 14.4g/t Au; and 49m @ 5.8g/t Au, 1.05% Cu, 0.10% Co, 0.42% Bi and 0.9g/t Ag.
- From drilling to test the extensions to the **Red Dome** gold–copper–molybdenum deposit, Queensland, **Kagara Ltd** reported an intersection of 63.45m @ 3.14g/t Au from 1002m. This intersection is the highest grade achieved during Kagara's drilling program over the past two years and opens up the potential for the Red Dome system at depth.
- **Frontier Resources Ltd** has several drill intersections of gold skarn at the **Stormont** deposit in the central north of Tasmania, the best being 6.6m @ 16.32g/t Au, 0.29% Bi and 4.8g/t Ag.
- At the **Tropicana** joint venture, 230 km east-south-east of Laverton, Western Australia, **AngloGold Ashanti Ltd** and **Independence Group NL** reported further encouraging regional exploration results. Independence announced that aircore drilling defined a 45 km anomalous gold corridor

trending northeast and southwest from the 4.05 Mozs Au Tropicana–Havana deposit and lying between the Black Dragon and Kamikaze prospects. Rock chip sampling adjacent to a hole at Black Dragon, 30 km northeast from Tropicana-Havana, returned assays including 22.2g/t Au, 16.7g/t Au and 15.9g/t Au. Follow-up sampling over the main high-grade zone returned 27 samples with grades in excess of 1g/t Au including 12 samples grading over 5g/t Au which included samples assaying at 573g/t Au, 324g/t Au, and 157g/t Au.

- **Avoca Resources Ltd** announced the discovery of gold mineralisation at its **Musket** Prospect, 40km southeast of the Trident mine at Higginsville, Western Australia. An intersection from a diamond drill hole returned 18m @ 10.9g/t Au from a depth of 68m. This drilling was to test shallow mineralisation defined by earlier RC drilling that included intersections of 3m @ 9.9g/t Au from 13 m, 10m @ 2.9g/t Au from 67m, and 16m @ 2.1g/t Au from 73m.
- **Integra Mining Ltd** reported high-grade gold intersections from an initial drilling program at the **Lucky Bay** prospect which is part of its Aldiss-Randalls project near Kalgoorlie, Western Australia. An intersection of 5m @ 25.93g/t Au was recorded. Other intersections include 14m @ 5.39g/t Au and 16m @ 4.64g/t Au which included 2m @ 10.57g/t Au.

Production

Australian gold production reported by the Australian Bureau of Agricultural and Resource Economics (ABARE) for 2008 was 215 tonnes, a reduction of 12% from the 2007 level. Australia's largest producer in 2009 was the Super Pit at Kalgoorlie 0.6 Mozs (19 tonnes) was produced. It was followed by the Telfer operation, also in Western Australia where production was almost 0.58 Mozs (18 tonnes). In 2008, Western Australia dominated Australian production with 134 tonnes, just under two-thirds of total Australian output but a reduction of 14% on the output achieved in 2007 (Table 2).

Table 2. Australian gold production 2004 to 2008.

	2004 (t)	2005 (t)	2006 (t)	2007 (t)	2008 (t)
New South Wales	29.14	28.05	27.04	34.89	31
Victoria	3.46	5.24	6.27	6.42	5
Queensland	23.16	23.99	21.47	20.81	18
South Australia	5.12	6.24	6.75	6.92	7
Western Australia	164.32	173.14	165.10	155.29	134
Tasmania	10.60	8.34	5.10	4.19	5
Northern Territory	22.27	16.55	14.03	16.54	15
Australia	258.07	261.53	245.76	245.04	215

Source: ABARE Australian Commodity Statistics 2008 and ABARE Australian Mineral Statistics, December Quarter 2008

World Ranking

The United States Geological Survey (USGS) estimates of world gold reserves of 47 000 tonnes an increase of 5000 tonnes over 2007. According to the USGS, South Africa still has the world's largest reserve of gold, which remained unchanged at 6000 tonnes (12.8%) although its proportion fell slightly. Also, according to the USGS, Australia has the equal second largest reserve with Russia, with each having approximately 11% of the world's holdings.

Data published by the USGS shows world mine production of gold in 2008 to be 2330 tonnes a reduction of 50 tonnes on the estimated 2006 production level. China remained the leading producer with 295 tonnes, followed by South Africa with 250 tonnes and the USA with 230 tonnes.

Industry Developments

A limited review of developments is available in the document *"Australian Mineral Exploration: A Review of Exploration for the Year 2008 - Extended Edition"* available for download from the Geoscience Australia web site. For a more comprehensive discussion of project development the ABARE report *"Minerals and Energy - major development projects – October 2008 listing"* is available for download from the ABARE website.

Some of the major developments are:

- **Boddington** (Newmont 100%) in Western Australia where milling is expected to start later in 2009 and production over the first five years is expected to average around 1 Mozs/yr. Average annual production over the current 15 year life of mine will be around 850 000 oz of gold and 30 000 tonnes of copper. Development at Boddington is over 70% completed.
- **St Barbara Ltd** commenced gold production at its Leonora operation, Western Australia, where the first pour marked the end of the three year redevelopment of the **Gwalia** underground mine.
- **Dioro Exploration NL** and its partner **La Mancha Resources Inc.** poured the first gold from ore mined underground at its **Frog's Leg** project near Kalgoorlie, WA.
- **Avoca Resources Ltd** commenced gold production at the **Trident** mine at its Higginsville Gold Project, Western Australia.
- **Straits Resources Ltd** opened its **Hillgrove** mine, New South Wales and plans to produce 20 000 oz Au, 10,000 tonnes Sb and 30 tonnes W annually

Iron Ore

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Iron (Fe) is ranked fourth in abundance in the Earth's crust and is a major constituent of the Earth's core. Iron rarely occurs as the native metal and is almost always found combined with oxygen as iron oxide minerals such as hematite (Fe_2O_3), magnetite (Fe_3O_4), goethite and limonite. Iron ores are rocks from which metallic iron can be economically extracted. Iron ore is one of the raw materials used to make pig iron, the main raw material in steel making. Almost all (98%) of iron ore is used in iron and steel making with small amounts used in areas such as coal washeries and cement manufacturing. When iron is alloyed with elements such as carbon, manganese, vanadium and nickel, harder and stronger steels are produced. Steel is used in many areas of manufacture including motor cars, ships, railway lines and rolling stocks, buildings, pipelines, white goods and heavy equipment.

The State of Western Australia dominates the Australian iron ore industry with nearly 97% of the total production. The Pilbara region is particularly significant with more than 84% of Australia's total identified resources and almost 92% of the production. Locally significant iron ore mines also operate in the Northern Territory, South Australia, Tasmania and New South Wales.

Resources

In 2008 Economic Demonstrated Resources (EDR) increased by 18% to 24 gigatonnes (Gt) mainly due to the inclusion of Abydos, Barrambie and Western Turner Syncline for the first time and large increases at the Yandi, Balla Balla, Jimblebar, Marandoo, Marillana, Mining Area C, Mount Karara, Pardoo and West Pilbara deposits. Western Australia has 98% of Australia's EDR with about 86% occurring in the Pilbara district. Magnetite ore currently constitutes 24% or 5.7 Gt of Australia's EDR.

Paramarginal Demonstrated Resources (PDR) remained constant at 0.3 Gt and Submarginal Demonstrated Resources (SDR) also remained relatively constant at 1.6 Gt. Inferred Resources increased by 18% to 28.9 Gt due the inclusion of Bonnie Creek, Mount Caudan, Railway, Yalleen, Yilgarn Project, Wonmunna and Western Creek for the first time and large increases at Yandi,

Balla Balla, Jack Hills, Jimblebar, Marillana, Mount Newman JV and Roy Hill. Western Australia has about 93% of Australia's total identified resources of iron ore with about 84% of the total identified resources occurring in the Pilbara Region.

Accessible EDR

Almost all EDR is accessible except for the remaining resource of 18 million tonnes (Mt) at Orebody 23 in the Newman District and 30% of the Windarling resource. Both have been quarantined for environmental reasons. The resource life of the accessible EDR of 23.9 Gt is about 70 years.

JORC Reserves

About 45% of accessible EDR, or 10.8 Gt, is JORC reserves compliant. The resource life of accessible JORC reserves is about 30 years. Rio Tinto and BHP Billiton manage 53% of the JORC reserves and magnetite ore constitutes 29% of the JORC reserves.

Exploration expenditure

The Australian Bureau of Statistics (ABS) data indicates that exploration expenditure for iron ore in 2008 totalled $583 million, a 64.6% increase on the $354.1 million spent in 2007. About $546 million or 93.7% was spent in Western Australia. Iron ore exploration accounted for 22.4% of the total mineral exploration expenditure in Australia in 2008.

Production

The Australian Bureau of Agricultural and Resource Economics (ABARE) reported that Australia's iron ore production in 2008 was 341.1 Mt (299.1 Mt in 2007) with 97% produced in Western Australia. Exports in 2008 totalled 310.2 Mt (267.2 Mt in 2007) with a value of $30.6 billion. ABARE has projected that Australia's iron ore production will increase from 324.7 Mt in 2007-08 to 504.9 in Mt 2013-14. Exports are projected to rise from 294.3 Mt to 473.5 Mt over the same period.

World ranking

In 2008, Australia had about 15% of world EDR of iron ore and was ranked third after Ukraine (19%) and Russia (16%). In terms of contained iron, Australia has about 17% of the world's EDR and is ranked second behind Russia (19%). Australia produces around 15% of the world's iron ore and is ranked third behind China (35%) and Brazil (18%).

Industry Developments

OVERVIEW

In 2008, three projects commenced iron ore shipments, Cloud Break (**Fortescue Metals Group**), Hope Downs (**Rio Tinto** and **Hancock Prospecting**) and Pardoo (**Atlas Iron**). The Rio Tinto owned Cape Lambert port expansion to 80 million tonnes per annum (Mtpa) was completed in November 2008 and the Port of Geraldton Berth 5 expansion to 12 Mtpa shipped the first ore in January 2008. Projects that were under construction during 2008 include, Mesa A (**Rio Tinto**), Brockman 4 (**Rio Tinto**), Rapid Growth Projects 4 and 5 (**BHP Billiton**), Sino Iron (**CITIC Pacific Mining**) and Cairn Hill (**IMX Resources**). At Port Hedland a new 18 Mtpa multi-user berth was under construction. There are more than 25 proposed iron ore projects which are at various stages of development ranging from scoping studies to marketing.

WESTERN AUSTRALIA

Rio Tinto Iron Ore: Site works commenced in January 2008 on the US$901 million Mesa A Project 50 kilometres (km) from Pannawonica in the Pilbara district. The project will have an initial capacity of 20 Mtpa in 2010 rising to 25 Mtpa in 2011. The Mesa A and Warrambo Channel Iron Deposits (CID) resources are being developed to replace the Mesa J operation, which will cease in 2010. Construction of the Brockman Syncline 4 project commenced in December 2007 and is due to be commissioned in 2010 with a capacity of 22 Mtpa. A US$149 million feasibility study is being undertaken into development of the Western Syncline deposit using existing plant and infrastructure

at Tom Price. Rio Tinto is investigating increasing production at the Yandicoogina mine by an additional 8 Mtpa to 52 Mtpa.

BHP Billiton: At the end of December 2008, the US$2.15 billion Rapid Growth Project 4 (RGP4) was nearing 70% completion. The project is due for completion in the first half of 2010 and is planned to increase capacity by 26 Mtpa to 155 Mtpa. RGP4 includes increasing production at Yandi to 45 Mtpa, developing a new crushing and screening plant and additional stockyards as well as train dumping facilities. In November 2008, BHP Billiton committed to the US$5.6 billion Rapid Growth Project 5 (RGP5) which is planned to increase the system capacity by 50 Mtpa to 205 Mtpa.

Fortescue Mining Group Ltd (FMG): The first ship to be loaded at the Fortescue Herb Elliott Port was the MV Heng Shan which left for Boasteel in China in May 2008 with 170 000 tonnes of "rocket" ore. The original capacity of the FMG Cloud Break project was 45 Mtpa although optimisation of the production process has the potential to increase capacity to 55 Mtpa in 2009. In February 2009, mining commenced at the Christmas Creek deposit with the ore being transported by road to the Cloud Break ore processing facility.

Hancock Prospecting: The first Hope Downs ore was shipped from the Port of Dampier in April 2008. Production at the US$364 million Hope Downs Stage 2 commenced in December 2008. The project increased the mine capacity from 22 to 30 Mtpa. A US$71 million feasibility study is investigating the development of the Hope Downs 4 deposit located 45 km east of the Hope Downs 1 mine. At Roy Hill 1 a 55 Mtpa, Marra Mamba ore operation is planned to commence in 2011.

Portman Ltd: In November 2008 Cliffs Natural Resources completed the takeover of Portman Ltd. The company is investigating the potential for the expansion of the Koolyanobbing operations beyond 8.5 Mtpa. At the Cockatoo Island Project construction of the Stage 3 seawall extension commenced in August 2008. Mining is expected to commence in mid-2009 with a two year mine life.

Mount Gibson Iron Ltd: At the 3 Mtpa Tallering Peak and the 4 Mtpa Koolan Island operations overburden cut-backs were suspended in late 2008. Construction at the $84 million Extension Hill project commenced in late 2008. Production of 3 Mtpa over six years is due to commence in 2010.

Extension Hill Pty Ltd: The company plans to produce 5 Mtpa of concentrate from the Extension Hill magnetite deposit commencing in 2011. The project will cost $715 million and includes a 280 km slurry pipeline to Geraldton.

Murchison Metals Ltd: The Jack Hills operation is expected to reach a production capacity of 1.8 Mtpa in 2009 with the commissioning of six new bottom dump triple trailer road trains. The Stage 2 mine feasibility study due for completion in 2009 envisages a 25 Mtpa mine commencing in 2011.

Midwest Corporation Ltd: Rail haulage of iron ore product commenced in late 2008 after the completion of the $3 million Tilley rail siding. The operation, which upgrades low grade stockpiles at Koolanooka, was recommenced in August 2008. **Sinosteel Corporation** completed a takeover of Midwest Corporation in September 2008. Midwest is planning to commence a 15 Mtpa direct shipping ore operation at Weld Range and is considering the 6 Mtpa Koolanooka magnetite concentrate project.

Grange Resources Ltd: The US$1.7 billion Southdown Magnetite and Kemaman Pellet Project is expected to produce 6.8 Mtpa of premium grade pellets from 2012. The project consists of a magnetite mine and concentrator at Southdown, a slurry pipeline to export facilities at the Port of Albany and a pellet production plant at Kemaman in Malaysia.

Gindalbie Metals Ltd: The $1.8 billion Karara Project consists of an initial 1.5 Mtpa hematite operation starting in late 2009 followed by an 8 Mtpa magnetite concentrate operation from late 2010. Infrastructure requirements include an 85 km rail spur line to Tilley Siding near Morawa and export shipping facilities at the Port of Geraldton.

Atlas Iron Ltd: Mining at the Pardoo Project commenced in October 2008 and the first shipment left Port Hedland in December 2008. The $18 million project has a capacity of 1 Mtpa and with the expenditure of another $14.5 million the capacity would rise to 3 Mtpa. Atlas is currently using the

Fortescue Herb Elliot port facilities. Atlas plans to commence production at the $10 million Wodgina Project in 2010. The planned 2 Mtpa of production will be trucked 100 km to Port Hedland for export. The $50 million Abydos Project, located 120 km south of Port Hedland, is expected to start in 2011 at a rate of 3 Mtpa. A preliminary feasibility study is due to be completed in 2009 on the Ridley Magnetite Project near the Pardoo Project.

China Metallurgical Group Corporation (MCC): In August 2008, **Cape Lambert Pty Ltd** completed the $400 million sale of the Cape Lambert magnetite project to MCC. The $600 million Cape Lambert magnetite project is only 5 km from the coast near Karratha. There is a plan to produce 7 Mtpa of concentrate during an initial 20 year mine life.

CITIC Pacific Mining: Construction of the $5.2 billion Sino iron ore project commenced in early 2008. Development of the Balmoral Central magnetite deposit during 2008 included bulk sampling, pre-stripping of overburden and bulk earthworks. When production commences in late 2009, 27.6 Mtpa of magnetite concentrates and pellets will be exported. Infrastructure will include a 450 megawatt (MW) gas fired power station, a desalination plant and a port at Cape Preston.

Australasian Resources Ltd (ARL): A bankable feasibility study on the $2.7 billion Balmoral South Project was completed in June 2008. ARL plans to mine 40 Mtpa of magnetite ore commencing in 2011 to produce 12 Mtpa of product, including 5 Mtpa of concentrates and 7 Mtpa of blast furnace pellets.

Golden West Resources Ltd: The Wiluna West Project is located 35 km southwest of Wiluna. The company is investigating commencing a 10 Mtpa direct shipping ore operation with product transported to either Oakajee or Esperance for export.

BC Iron Ltd: The $20 million Nullagine Iron Ore Project is planned to produce 1.5 Mtpa of direct shipping ore (DSO) by 2010. The project is located close to the infrastructure at Fortescue Metal Groups Cloud Break operation.

Ferrowest Ltd: The $700 million Yalgoo Iron Project located 14 km east of Yalgoo is aimed at producing pig iron from the Yogi magnetite deposit. The 1 Mtpa pig iron operation is expected to commence in 2012.

Aurox Resources Ltd: The proposed $1 billion Balla Balla Titanomagnetite Project is expected to produce 6 Mtpa of concentrate (58% Fe, 1% V_2O_5 & 14% TiO_2) from 2010 over an initial 15 year mine life. The concentrate will be transported to Port Hedland via a 110 km slurry pipeline. A phosphate rich overburden could potentially produce up to 1 Mtpa of a saleable phosphate product.

Australian Premium Iron Joint Venture: At the West Pilbara Iron Ore Project a 25 to 30 Mtpa operation, including port and rail infrastructure, is estimated to cost US$3.9 billion. The first shipments are planned to start in 2012.

Iron Ore Holdings Ltd: In July 2008, the company entered into an arrangement with Rio Tinto for mine-gate iron ore sales of up to 1.5 Mtpa of pisolite ore. The $10 million project is anticipated to start in late 2010 with trucks hauling ore 9 km from Phil's Creek to the Yandicoogina ore stockpiles.

FerrAus Ltd: A number of options are being considered to develop the Davidson Creek and Robertson Range iron ore deposits including a 2 Mtpa operation that would truck ore 50 km to the Jimblebar mine for railing to Port Hedland.

Brockman Resources Ltd: The company intends to commence mining at the Marillana Project at a rate of 15 to 25 Mtpa in 2012.

Polaris Metals NL: The $120 million Stage 1 Yilgarn Iron Ore Project is located 60 km north of Koolyanobbing. Polaris is investigating an initial production of 2.5 Mtpa from the Carina deposit. Ore would be trucked to a siding on the Trans Australia rail line and then railed to either Fremantle or Esperance for export.

United Minerals Corporation: At the Railway Marra Mamba deposit a number of development options are being considered. The 10 Mtpa preferred option includes the construction of a rail spur to a nearby rail line with production commencing in 2011.

Iron ore mining at Francis Creek mine, Northern Territory (Territiry Resources Ltd)

Moly Mines Ltd: At Spinifex Ridge a $12 million 1 Mtpa open-pit mine is proposed to start in 2010 with an initial five year mine life. Iron ore is planned to be trucked 170 km to Port Hedland for export.

SOUTH AUSTRALIA, TASMANIA AND NORTHERN TERRITORY

OneSteel Ltd: In February 2008, OneSteel announced Project Magnet Phase 2 at the Whyalla operation in South Australia. OneSteel plans to increase iron ore reserves and increase iron ore exports to 6 Mtpa by 2010.

Western Plains Resources Ltd (WPR): In January 2009 the Commonwealth of Australia granted formal approval for the construction of the Peculiar Knob mine inside the Woomera Prohibited Area in South Australia. WPR plans to develop the $62 million Peculiar Knob Project at 3 Mtpa from 2009 with the Buzzard and Tui deposits brought into production one to two years later. Product would be trucked 85 km to the Wirrida Siding then railed to a port for export. WPR is investigating producing 6 Mtpa of magnetite concentrates from the Hawks Nest deposit from 2012.

IMX Resources NL: In mid-2008, trial mining was undertaken at the Cairn Hill magnetite-copper-gold project in South Australia. A $54 million Phase 1 operation aims to produce up to 1.4 Mtpa of run-of-mine ore commencing in 2009. IMX Resources plans to truck ore 58 km to the Wirrida rail siding followed by rail haulage to Darwin for export to the Tonghua Mining processing plant in China.

Centrex Metals Ltd: At the Wilgerup hematite project on the Eyre Peninsula of South Australia a 1.6 Mtpa operation is planned to commence in 2010 over an initial six year mine life. The ore will be trucked 17 km to the Tooligee rail siding then railed to a port such as Port Lincoln for export.

Ironclad Mining Ltd: The Wilcherry Hill Project is located on the Eyre Peninsula of South Australia. A bankable feasibility study investigating a possible 2 Mtpa magnetite concentrate operation is expected to be completed in 2009.

Grange Resources Ltd: At Savage River in Tasmania a $90 million expansion is planned to increase production from 2.3 Mtpa of pellets to 2.9 Mtpa by 2011. In January 2009 a merger was completed between Grange Resources and Australian Bulk Minerals the manager of the operation.

Territory Iron Ltd: At Frances Creek in the Northern Territory a mobile wet plant and an additional crushing plant was commissioned in January 2009 to increase capacity to 3 Mtpa.

IRON AND STEEL

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

- **Bluescope Steel Ltd:** Steel production at Port Kembla
- **Onesteel Ltd:** Steel production at Whyalla, Rooty Hill, Mayfield and Laverton North.
- **HIsmelt:** In early 2009 operations at the HIsmelt facility at Kwinana in Western Australia were placed on care and maintenance.
- **Ferrowest Ltd:** A 1 Mtpa pig iron project is planned to commence at Yalgoo in Western Australia in 2012. Ferrowest plans to use the Midrex Technologies ITmk3 process to produce the pig iron.
- **Boulder Steel Ltd:** A $700 million seamless tube plant is planned to be built at Gladstone in Queensland. The 400 ktpa project includes the construction of a pig iron plant.

INFRASTRUCTURE

BHP Billiton: BHP Billiton is undertaking a pre-feasibility study which is targeting an iron ore system capacity of 240 Mtpa by 2012. The Quantum Project is considering the development of the Outer Harbour at Port Hedland. Stage 1 envisages increasing capacity to 300 Mtpa by 2015 with Stage 2 further increasing the iron ore system capacity to 350 Mtpa.

Rio Tinto Iron Ore: In November 2008 the US$860 million Cape Lambert expansion project was completed, increasing port capacity from 55 to 80 Mtpa. Rio Tinto is planning the Cape Lambert 180 Project to increase port capacity to 180 Mtpa. The Remote Operations Centre, which will manage the Pilbara mines and infrastructure 1300 km away near the Perth Airport, is scheduled for completion in 2009.

Port Hedland Port Authority: A new $225 million multi-user berth is expected to be operational in 2009 with a capacity of 18 Mtpa. Shipping began from the 45 Mtpa Fortescue Herb Elliot Port in May 2008 and a second berth was completed in December 2008.

Port of Geraldton: The $35 million Berth 5 Iron Ore Expansion Project shipped the first ore in January 2008. The expansion project increased the port's iron ore handling capacity to 12 Mtpa. Oakajee Port and Rail Pty Ltd (Murchison Metals 50%) was selected in July 2008 by the Western Australian Government as the preferred developer of the Oakajee deep water port located 25 km north of Geraldton.

Port Bonython: In October 2008, the South Australian Government awarded preferred tenderer status for the development of Port Bonython to the Spencer Gulf PortLink Consortium. The new iron ore port is expected to be operational in 2011.

Lithium

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Lithium (Li) is recovered from the mineral spodumene ($Li_2O.Al_2O_3.4SiO_2$) and lithium-rich brines. It is used in a range of products such as ceramics, glass, batteries and pharmaceuticals. Lithium use has expanded significantly in recent years as a result of increasing use in rechargeable batteries for portable electronic devices such as mobile phones, computers and rechargeable power tools as well as in batteries and electric motors for hybrid and electric cars.

Lithium produced from the Greenbushes mine in southwest Western Australia (WA) has been used in the production of specialty glasses, glass bottles, ceramics and ceramic glazes. Its ore also is a feedstock for the production of lithium carbonate used in the chemical industry. These chemical industry uses include greases, aluminium production, air conditioning systems and catalysts.

Resources

Australia's Economic Demonstrated Resources (EDR) increased by 180% in 2008 to 584 kilotonnes (kt) of lithium. The bulk of Australia's lithium resources are in the Greenbushes spodumene deposit, 250 kilometres (km) south of Perth, WA. It is the world's largest and highest grade spodumene deposit. All of lithium EDR is accessible for mining.

In 2008, Subeconomic Resources, all in the submarginal category, total 25 kt accounting for 4% of total Demonstrated Resources. Inferred Resources amounted to 25 kt. Western Australia accounts for all the Subeconomic and Inferred Resources.

Exploration

There are no statistics available on exploration expenditure for lithium, however only a few companies are exploring for lithium in WA and Qld.

Production

According to the WA Department of Mines and Petroleum, the Talison Minerals' Greenbushes operation produced 239 528 tonnes of spodumene concentrate in 2008, containing between 4.8% and 7.5% Li_2O.

World Resources

Based on United States Geological Survey (USGS) estimates for 2008, which have been modified by Geoscience Australia for Australia's resources, world lithium resources totalled 4514 kt, although the resource data does not include some important producing countries such as Argentina and Portugal. According to the USGS, of the total world resources, Chile holds approximately 3000 kt, followed by Australia with 584 kt, China with 540 kt, Brazil with 190 kt and Canada with 180 kt.

Lithium resources occur in two distinct categories, lithium minerals and lithium-rich brines. Canada, China and Australia have the most significant resources of lithium minerals while lithium brine is produced predominantly in Chile, followed by Argentina, China, Russia and the USA. Lithium brines are the dominant feedstock for lithium carbonate production.

World production in 2008 was estimated by the USGS to be 27 kt of contained lithium, excluding the USA production for commercial reasons. Based on the USGS data, Chile produced 12 kt to remain the world's largest producer in 2008 followed by Australia, China and Argentina.

Industry Developments

The demand for lithium is forecast to grow as a result of the increased use of rechargeable batteries in electronic devices and the development of lithium-ion batteries to power hybrid and electric cars.

In the wake of this increasing demand, **Talison Minerals Pty Ltd** is upgrading the high and low grade sections of its lithium minerals processing facility at Greenbushes mine, WA. The company's lower grade spodumene is exported to China where it is converted into a range of lithium chemicals. The higher grade spodumene is exported to Europe, Asia and the USA where it consumed by the glass, ceramics, steel, and foundry industries. The Greenbushes mine has a spodumene capacity of 250 000 tonnes per annum (tpa).

Galaxy Resources Limited is at an advanced stage of developing its Mount Cattlin lithium project (hard-rock spodumene) near Ravensthorpe, WA. The project encompasses a mine and processing plant, which will produce 137 000 tpa of 6% Li_2O spodumene concentrate. The company plans to commence production during third quarter 2010. Galaxy Resources proposes to build a downstream lithium carbonate chemical facility in Jiangsu Province, China, which will produce 17 000 tpa of lithium carbonate. The Mount Cattlin deposit has a reported JORC-compliant resource of 14.4 million tonnes with average grade 1.08% Li_2O and 153 parts per million Ta_2O_5 containing an estimated 155 000 tonnes of lithium oxide (Li_2O) and 219 000 tonnes of tantalum pentoxide (Ta_2O_5).

Magnesite

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Magnesite (magnesium carbonate $MgCO_3$) is marketed in three main forms:

- crude magnesite, primarily for use in chemicals and agriculture
- dead-burned magnesia, a durable refractory for use in cement, glass, steel and in metallurgical industries
- caustic calcined magnesia, for use in making oxychloride and oxysulphate cements for flooring and wallboards, mouldings and acoustic tiles as well as various environmental and chemical applications.

Resources

Economic Demonstrated Resources (EDR) of magnesite remained unchanged at 344 million tonnes (Mt) in 2008. South Australia (SA) has Australia's largest holding of EDR with 235 Mt of magnesite, which is unchanged from 2006.

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

The third largest inventory of EDR is in Tasmania (Tas) where the Arthur River deposit has an indicated resource of 26 Mt. Magnesite in the deposit typically grades at 42.8% magnesium oxide (MgO) and is part of a much larger global resource of 195 Mt in the Arthur-Lyons River area, about 53 km south of Burnie in Tas.

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

Subeconomic Demonstrated Resources of 57 Mt of magnesite remained unchanged from 2006. All of these resources occur in Qld and Tas.

Inferred Resources remained steady at 931 Mt with Qld accounting for 50% followed by South Australia (SA) with 31% and Tas with 16%. The remaining resources are in NSW and the NT.

Accessible EDR

All magnesite EDR is accessible for mining.

JORC Reserves

About 11% of AEDR comprise JORC Code reserves. The remainder represents resources assessed by Geoscience Australia from the measured and indicated categories of industry reported mineral resources as defined under the JORC Code and other classification systems used by companies not listed on the Australian Stock Exchange. At Australia's 2007 rate of production, magnesite resources in the JORC Code reserves categories are adequate for 84 years.

Exploration

Data relating to exploration expenditure for magnesite are not published by the Australian Bureau of Statistics (ABS).

Production

The bulk of Australia's magnesite production was by Queensland Magnesia Pty Ltd which supplies high-grade electrofused and deadburned magnesia to the global refractory market, as well as calcined magnesia for a wide range of applications. In 2007-08, the company produced 124 681 tonnes of raw magnesite. About 1530 tonnes of magnesite was produced from the Myrtle Springs region in SA during 2007-08.

The United States Geological Survey (USGS) data indicate that China (45%), Turkey (13%), North Korea and Russia (8% each) were the largest producers of magnesite in 2008.

World Ranking

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

Industry Developments

Queensland Magnesia Pty Ltd announced plans to expand its total magnesia capacity from 220 000 tonnes per annum (tpa) to 320 000 tpa, add a third multiple hearth furnace and diversity its markets into hydrometallurgical and agricultural applications. Construction of the third multiple hearth furnace is scheduled to be completed in December 2009.

Manganese Ore

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Manganese is the twelfth most abundant element in the Earth's crust and accounts for about 0.1% of its composition. Manganese is found in many minerals but the two main manganese minerals are pyrolusite (MnO_2) and rhodochrosite ($MnCO_3$). Manganese is essential to iron and steel making because of its sulphur fixing, deoxidising and alloying properties as well as its low cost. About 90% of manganese production is used in manufacturing iron and steel, resulting in it being the fourth most used metal in terms of tonnage after iron, aluminium and copper. The most important use of manganese after iron and steel is in dry cell batteries in the form of electrolytic manganese dioxide (EMD). Manganese is important also as an alloying element in aluminium and copper and is an essential trace nutrient in plant fertilisers and animal feeds. Manganese compounds are used as pigments and for colouring ceramics and glass.

In Australia, there are two operations in the Northern Territory, one on Groote Eylandt in the Gulf of Carpentaria and another at Bootu Creek 110 km north of Tennant Creek. There are three operations also in Western Australia, two at the Woodie Woodie mine about 400 km southeast of Port Hedland and another at Peak Hill 600 km south of Port Hedland. Manganese ore processing plants are operated by **TEMCO** at Bell Bay in Tasmania and by **Delta plc** at Newcastle in New South Wales.

Resources

In 2008, Australia's EDR of manganese ore increased by 9.9% to 181 million tonnes (Mt) with increases in EDR at Balfour Downs and Bootu Creek. Paramarginal Demonstrated Resources remained unchanged at 23 Mt and Submarginal Demonstrated Resources also remained unchanged at 167 Mt. Inferred Resources decreased 2.9% to 133 Mt mainly as a result of a decrease at Balfour Downs.

Accessible EDR

All manganese ore EDR (181 Mt) is accessible. The resource life is about 19 years at current rates of production of beneficiated manganese ore.

JORC Reserves

Manganese ore JORC reserves are 152 Mt (84% of accessible EDR). The resource life based on JORC reserves and at the current rate of production of beneficiated manganese ore is about 16 years.

Exploration expenditure

Data relating to exploration expenditure for manganese are not published by ABS on either a state or national basis. Companies which are actively exploring for manganese include Shaw River Resources at the Baramine Project, Monax Mining at the Waddikee Project, Spitfire Resources at the South Woodie Woodie Project and Aurora Minerals at the Capricorn Project.

Production

ABARE reported that Australia produced 4.8 Mt of beneficiated manganese ore in 2008 (5.2 Mt in 2007). Exports for 2008 totalled 4 Mt (4.8 Mt in 2007) valued at A$2,021 million (A$712 million 2007).

World ranking

Australia has 13% of the world's EDR of manganese ore and is ranked fourth behind Ukraine (30%), South Africa (15%) and China (15%). Australia produces 12% of the world's manganese ore and is ranked third behind China (34%) and South Africa (16%).

Industry Developments

NORTHERN TERRITORY

GEMCO: The US$180 million expansion project on Groote Eylandt is expected to be completed in the first half of 2009. The installed capacity is planned to increase by one million tonnes per annum (Mtpa) to 4.1 Mtpa of manganese concentrates. In 2008 work was completed on Tailing Storage Facility 9 (or Dam 9) to replace dams which were nearing full capacity. In late 2008, the rehabilitation of Dam 5 and F3 quarry commenced to restore about 80 hectares of land. During 2009 GEMCO plans to explore for manganese ore in its eastern leases in an attempt to extend the life of the mine.

OM Holdings Ltd: At Bootu Creek the process plant performance during 2008 demonstrated an annualised production rate of 700 kilotonnes per annum (ktpa) of manganese concentrate which is above the design capacity of 550 ktpa. In August 2008, approval was given to construct a crushing and reprocessing plant for the heavy media drum plant rejects. The A$12.6 million project will increase capacity to about 800 ktpa. The Muckaty rail siding extension has been postponed and is now planned to be completed when the additional rail capacity is required. A new contractor who commenced in December 2008 with new and larger mining equipment has improved productivity.

WESTERN AUSTRALIA

Consolidated Minerals Ltd: In January 2008, **Palmary Enterprises (Australia) Pty Ltd** acquired 100% of Consolidated Minerals Ltd. **HWE Mining Ltd** removed 3.15 million bank cubic metres of waste at a number of open-pits at the Woodie Woodie mine. Ore is processed through a heavy media separation plant to produce a lump and fine product which is loaded into road trains with 90 tonnes capacity for transportation to Port Hedland.

Mineral Resources Ltd: A 400 ktpa tailings re-treatment plant operates at Woodie Woodie. In May 2008, a 240 ktpa operation commenced at Peak Hill. The project produces a +50% ferruginous manganese product for export through Port Hedland. In August 2008, Mineral Resources Ltd and the **Hancock Balfour Downs Pty Ltd/Gaynor Park Pty Ltd** of the Hancock Prospecting Group entered into an agreement to develop the Balfour Downs manganese deposit in the East Pilbara region. Initially the project is expected to produce up to 350 ktpa of manganese concentrates.

Hi-Tec Energy Ltd: In April 2008 the **Mesa Mining Joint Venture** was formed between Hi-Tec Energy (50%) and **Auvez Resources Ltd** (50%) to develop the Sunday Hill and Ant Hill manganese resources. In late December 2008, a 30 kilotonnes (kt) trial shipment of ore from Ant Hill was awaiting transportation to Port Hedland. The Mesa Mining Joint Venture plans to mine 200 ktpa of

ore from late 2009. Hi-Tec Energy plan to construct a 20 ktpa granulated manganese sulphate plant at Port Hedland at a cost of around A$20 million. The plant would process low grade fines from Ant Hill. Hi-Tec also plans to produce 27 ktpa of a micronutrient fertiliser using the tailings material from the Port Hedland plant.

Mineral Sands

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The principal components of mineral sands are rutile (TiO_2), ilmenite ($FeTiO_3$), zircon ($ZrSiO_4$) and monazite ([Ce,La,Th]PO_4). Rutile and ilmenite are used dominantly in the production of titanium dioxide pigment. Less than 4% of total titanium mineral production, typically rutile, is used in making titanium sponge metal. Zircon is used as an opacifier for glazes on ceramic tiles, in refractories and for the foundry industry. Recently there has been some interest in monazite as a source of thorium for possible use in thorium nuclear reactors for electricity generation.

Resources

Economic Demonstrated Resources (EDR) of ilmenite decreased by 4.1% to 212.3 million tonnes (Mt) in 2008, down from 221.3 Mt in 2007. About 58% of Australia's EDR of ilmenite is in Western Australia (WA) and 20% is in Queensland (Qld) with the remainder in Victoria (Vic), 11.5%, New South Wales (NSW), 7.5% and South Australia (SA), 2.9%.

EDR of rutile, which includes some leucoxene in WA, decreased by 0.9% from 23.1 Mt in 2007 to 22.9 Mt in 2008. Victoria has the largest share of Australia's rutile EDR with 33.2% followed by Qld (25.3%), NSW (19.7%), WA (18.8%) and SA (3.1%).

EDR of zircon increased slightly from 39.0 Mt in 2007 to 39.2 Mt in 2008 with WA (32.2%), Vic (23.4%) and Qld (20.9%) accounting for most of Australia's zircon EDR. The balance was in SA (13.8%) and NSW (9.4%).

Australia's Subeconomic Demonstrated Resources of ilmenite, rutile and zircon in 2008 amounted to 23.8 Mt of ilmenite, which was a reduction of 32.5% on 2007, 6.6 Mt of rutile, a decrease of 32% on the previous year, and 10 Mt of zircon, a decrease of 32.4% on 2007.

Inferred Resources of ilmenite decreased by 3.8% in 2008 to 123.2 Mt. Victoria has the largest proportion of inferred ilmenite resources with 45.5% of the Australian total followed by NSW (25%), WA (12.9%) and Qld (11.9%).

Inferred Resources of rutile increased to 32.1 Mt from 31 Mt in 2007. Victoria has the largest share of Australia's inferred rutile resources with 50.2% of the Australian total followed by NSW (35.2%), Qld (5.9%), SA (5.6%) and WA (3.3%).

Inferred Resources of zircon increased to 36.5 Mt from 35.7 Mt in 2007. Victoria is the main holder of zircon Inferred Resources with 59.5% of the Australian total, followed by NSW (20%), WA (8.8%) and Qld (7.4%).

Accessible EDR

A significant portion of mineral sands EDR is in areas quarantined from mining because they are largely incorporated in national parks. Geoscience Australia estimates that around 17% of ilmenite, 25% of rutile and 21% of zircon EDR is unavailable for mining. Deposits in this category include Moreton Island, Bribie Island and Fraser Island, the Cooloola sand mass, the Byfield sand mass and the Shoalwater Bay area, in Qld and the Yuraygir, Bundjalung, Hat Head and Myall Lakes National Parks in NSW.

JORC Reserves

Approximately 24% of ilmenite, 30% rutile and 31% zircon of accessible EDR (AEDR) comprise JORC Code Reserves. The remaining AEDR represents resources assessed by Geoscience Australia from the

Heavy mineral sands operation at Jacinth-Ambrosia deposit, Eucla Basin, South Australia (Iluka Resources Ltd)

Measured and Indicated categories of industry reported mineral resources as defined under the JORC Code and other classification systems used by companies not listed on the Australian Stock Exchange.

At the rate of production in 2008, Australia's AEDR of ilmenite, rutile and zircon is sufficient for an average of 86 years for ilmenite, 53 for rutile and 56 for zircon. However, resources in the JORC Code Reserves categories are adequate for only 21 years for ilmenite, 16 for rutile, and 18 for zircon.

Exploration

According to quarterly Australian Bureau of Statistics (ABS) figures, expenditure on exploration for mineral sands in 2008 increased marginally to $37.5 million compared with $36.5 million in 2007.

Production

In 2008, Australia produced 2.042 Mt of ilmenite, 325 000 tonnes of rutile, 158 000 tonnes of leucoxene and 550 000 tonnes of zircon compared with 2.042 Mt of ilmenite, 312 000 tonnes of rutile, 170 000 tonnes of leucoxene and 601 000 tonnes of zircon in 2007. About 1.018 Mt of ilmenite was exported during 2008 while rutile (439 000 tonnes) and zircon (655 000 tonnes) exceeded the level of production for the two commodities. The ilmenite not exported was upgraded to synthetic rutile containing about 92-94% TiO_2. In 2008, Australia produced 511 000 tonnes of synthetic rutile compared with 726 000 tonnes in 2007.

World Ranking

According to Geoscience Australia and the United States Geological Survey (USGS) data, Australia has the world's largest EDR of rutile and zircon with 50%, and 47%, respectively and has the second largest share of the world's ilmenite with 17%, behind China, which has 30%. Other major country rankings include India (13%), Brazil (10%) and South Africa (10%) for ilmenite; South Africa (18%) and India (16%) for rutile; and South Africa (25%) and Ukraine (7%) for zircon.

In 2008, world production of ilmenite remained steady at 10.4 Mt, rutile increased marginally to 624 000 tonnes, and zircon increased by 36% to 1.75 Mt. Australia is the largest producer of rutile with about 52% of the world production followed by South Africa with 19% and Sierra Leone with

15%. Australia is the second largest producer of ilmenite also with 19.7% after South Africa with 20% and is the second largest producer of zircon with 32% after South Africa at 37%.

Industry Developments

Companies which produced heavy mineral sands during 2007 were Iluka Resources Ltd, Bemax Resources Ltd, TiWest joint venture and Doral Mineral Sands Pty Ltd, all in WA and Consolidated Rutile Ltd in Qld. Iluka and Bemax also produced heavy minerals in the Murray Basin in Vic and NSW respectively while production continued from the recently commissioned Mindarie heavy minerals project, held by Australian Zircon NL, in SA. However, mining activities were terminated at the Goondicum alluvial/eluvial deposit near Monto in Qld and at Matilda Mineral's Andranangoo deposit on the Tiwi Islands off the Northern Territory (NT).

Iluka Resources Ltd heavy mineral sand operations in WA are located in two regions:

- The ***mid-west region*** north of Perth comprises the main mines of Eneabba (two wet concentrators, five mining units) and Gingin (wet concentrator, one mining unit). The company's Narngulu facility at Geraldton, includes mineral separation, zircon finishing and synthetic rutile plants as well as port operations and storage facilities at Geraldton. Iluka plans to use the Narngulu plant to process heavy mineral concentrates from the development of its Jacinth-Ambrosia deposits in the Eucla Basin in SA.
- In its ***south west region*** of mining activities, Iluka is realigning its production facilities to concentrate on zircon and high grade titanium dioxide products with less emphasis on lower grade material such as sulphate ilmenite. In accordance with its market policy, Iluka is restructuring its WA operations to focus on synthetic rutile high grade ilmenite feed. It has decided also to cease mining operations at Wagerup and Waroona where the remaining production output is mainly lower value sulphate ilmenite. Mining was completed at Wagerup in January 2009 and the only mining operation in south west WA, at Waroona is planned to close by October 2009. Mining was also closed at Cloverdale. Iluka will consider commencement of mining operations at its Tutunup South deposit, in 2010.

The production of heavy mineral sand commodities in 2008 from Iluka's mining and processing activities in WA amounted to 73 837 tonnes rutile, 467 222 tonnes synthetic rutile, 988 155 tonnes ilmenite, 10 629 tonnes of HiTi (mixture of rutile and leucoxene) and 188 003 tonnes zircon.

Because of weaker demand for its products, Iluka decided to idle two of its four synthetic rutile plants (SR1 in the south-west and SR4 in mid-west), one of the two concentrators at Eneabba in mid-west and one of its mineral processing plants in south-west WA.

Iluka Resources Ltd's Douglas project in Vic is based on the resources of three main deposits, Bondi Main, Bondi West and Bondi East. The infrastructure includes a single mining unit plant, a wet concentrator plant and a mineral separation plant located at Hamilton to produce the final specification rutile and zircon. The Hamilton mineral separation plant was shut down for capacity upgrade for the anticipated additional feedstock from the Murray stage 2 development at Kulwin. Production from the Douglas mine in 2008 totalled 66 261 tonnes rutile, 5847 tonnes leucoxene and 112 728 tonnes zircon.

In addition to the Douglas project, the company has a group of deposits at Ouyen in north west Vic, with two thirds of the company's heavy mineral resources in Murray Basin at Kulwin, Woornack, Rownack, Rainlover, and Pirro along with another group at Euston in NSW named Castaway, Kerribee, Earl, Dispersion and Koolaman. The commissioning of the mining project at Kulwin commenced in August 2009.

In the Eucla Basin in SA, Iluka holds the Jacinth-Ambrosia and Gulliver's deposits and has a joint venture agreement with Adelaide Resources Ltd over the Tripitaka deposit. The construction of the Jacinth-Ambrosia project was 80% complete in August 2009 and the first production of heavy mineral concentrate (HMC) could be as early as December 2009. The company anticipates processing the Jacinth-Ambrosia HMC at its Narngulu and Hamilton mineral separation plants while the ilmenite feed may be sent to the mid-west or south-west kilns.

Continuing exploration by the company in 2008 also led to the discoveries of heavy mineral deposits, including the Endeavour deposit in the NSW portion of Murray Basin.

To the end of 2008, Consolidated Rutile Ltd's operations at the Yarraman and Enterprise mines on North Stradbroke Island produced 74 030 tonnes rutile, 52 644 tonnes zircon and 202 021 tonnes ilmenite. The company reported a decreased ore throughput of 8% compared to 2007 achieving 50.7 Mt from both mine sites. The company announced on 13 May 2009 that it will move from the current two mine operation to a single mine operation when mining at Yarraman mine is completed in 2013. Consolidated Rutile Limited was taken over by Unimin Australia Limited in mid 2009.

Exxaro Resources Ltd has a 100% shareholding in Australia Sands which has as a principal asset 50% ownership in the TiWest Joint Venture with Tronox Incorporated. Tiwest operates an integrated titanium dioxide project in WA incorporating a dredging and dry-mining heavy mineral sands operation at Cooljarloo, dry separation and synthetic rutile plants at Chandala and a titanium dioxide pigment plant at Kwinana. Production in 2008 was approximately 348 000 tonnes of ilmenite, 58 000 tonnes of zircon, 26 000 tonnes of rutile, 32 000 tonnes of leucoxene, 226 000 tonnes of synthetic rutile and 86 000 tonnes of TiO_2 pigment. Exxaro reported in its 2008 annual report that the Dongara feasibility study is under way and will be completed by 2009, but production is not planned to start before 2011. The Dongara deposit has the resources to provide feedstock to the Chandala mineral separation plant for six years. Exxaro is also funding a $100 million Tiwest Kwinana pigment expansion project for an additional 40 kilotonnes per annum (ktpa) production with a commissioning target during the first quarter of 2010.

The heavy mineral resources/reserves controlled by Bemax are located in old shorelines in two provinces – the Murray Basin of Vic and NSW, and the south west region of WA.

Bemax Resources Limited (a controlled entity of Cristal Australia Pty Ltd) reported that its total resource in the Murray Basin increased from 2944 Mt at 2.9% heavy minerals or 86.5 Mt of contained heavy mineral at 31 October 2007 to 3185 Mt at 3.0% heavy minerals (94.4 Mt of contained heavy mineral) at 31 October 2008. The increase has occurred with the discovery of the Snapper South, Phoenix and Benbow deposits in NSW and with the extension of the Mercury deposit in Vic. These deposits increased the resource base by 8.5 Mt of contained heavy mineral. The mining at Ginkgo has decreased the resource by 600 000 tonnes of contained heavy minerals.

Bemax's operations in the Murray Basin include the Ginkgo mine and the Broken Hill mineral separation plant. During 2008, the company continued with the development of the Snapper deposit which is about 10 kilometres (km) from the Ginkgo mine and by mid-2009 the excavation of the start up mining pit and construction of tailings storage area were completed at the Snapper deposit.

Bemax's Ginkgo production in 2008 totalled 191 134 tonnes ilmenite, 114 406 tonnes other titanium minerals, 71 285 tonnes rutile and 52 585 tonnes zircon.

Bemax's heavy mineral sand mining in south west region of WA continued at Gwindinup, about 30 km south of the company's mineral separation plant at Bunbury. The Gwindinup deposits have a mine life of more than nine years and the nearby Happy Valley deposits are being progressed through environmental assessment and public consultation processes and will further extend the mine life of the project. Heavy mineral production from Bemax's operations in the region amounted to 147 881 tonnes of sulphate and secondary ilmenite and leucoxene, and 13 985 tonnes zircon.

Australian Zircon NL reported that its Mindarie zircon mine in the western Murray Basin, 148 km east-north-east of Adelaide, SA, produced 8573 tonnes of ilmenite, 3020 tonnes of rutile and 5959 tonnes of zircon in 2008. During the first half of 2009 the company was in the process of conducting modifications to its mobile slurry unit and the concentrator plant in order to improve the heavy mineral concentrate grades and recoveries.

Australian Zircon NL also is earning an 80% participating interest in its WIM 150 joint venture with Austpac Resources NL. Australian Zircon reported that stage one of a bankable feasibility study has been commenced on the WIM 150 deposit. Previous test work has shown that conventional feed

preparation techniques will successfully recover 85 to 90% of raw feed zircon to an acceptable grade heavy mineral concentrate.

In 2008, Austpac Resources NL completed the construction of stages 1 and 2 of a 3000 tonnes per annum (tpa) Enhanced Roasting and Magnetic Separation Synthetic Rutile (ERMS SR) synrutile demonstration plant on its site on Koogarang Island near Newcastle in NSW. The purpose of the plant is to produce samples of high grade synrutile and iron pellets from various ilmenite deposits for market assessment. Stage 1 is the ilmenite roasting section of the plant while stage 2 comprises ilmenite leaching/synrutile production and acid regeneration sections of the plant. Austpac secured samples of ilmenite from Consolidated Rutile Ltd North Stradbroke mine in Qld, from Bemax's Ginkgo mine in NSW and from BHP Billiton's Corridor Sands deposit in Mozambique. By late October 2008, Austpac reported that its plant produced very high grade synrutile (plus 97% TiO_2). BHP Billiton acquired a licence to use the ERMS SR process on its Corridor Sands heavy mineral deposit in Mozambique. The process was successful also in producing high grade synrutile from ilmenite samples from the Murray Basin deposits. Austpac plans to commercialise the ERMS SR technology by building a 60 000 tpa synrutile plant in eastern Australia, subject to the completion of a bankable feasibility study.

Monto Minerals Limited encountered mining problems with its Goondicum industrial minerals operation (ilmenite, feldspar, apatite and titanomagnetite) where mining commenced in October 2007. The Goondicum plant was unable to maintain adequate and consistent feed supply, and, following the appointment of Administrators in 2008, independent engineers were engaged to provide capital estimates for rectification and expansion of the plant to final phase capacity. In order to raise capital for reconstruction of the plant, creditors of Monto Minerals approved a recapitalisation proposal at a meeting on 11 June 2009, and a new prospectus was lodged with the Australian Securities and Investments Commission (ASIC) in September 2009.

Gunson Resources Ltd has commenced mine design definition study on its Coburn heavy mineral sand deposits in WA. In April 2008, Gunson reported that the total JORC-compliant Indicated and Measured Resources at Coburn increased to 728 Mt averaging 1.2% heavy minerals.

Image Resources Ltd continued extensive exploration activities in their tenement areas in the north Perth Basin. In May 2008, Image Resources reported Indicated and Inferred Resources for seven deposits totalling 206 Mt averaging 2.4% heavy minerals containing 6.4 Mt of heavy minerals. A scoping study to assess the potential economics of these resources was completed in December 2008 which identified that a stand alone dredging operation was the best option with a best case net present value (NPV) of $87 million (internal rate of return (IRR) 105%) plus addition value in processing ilmenite to synthetic rutile. During the first half of 2009 Image reported it had identified unexpectedly high grades of zircon in its Atlas deposit (18% to 21% of the heavy mineral fraction). Image also reported it had located heavy mineral concentrations at its Serpentine Lakes tenements situated along strike from Diatreme Resources Ltd's zircon-rich Cyclone heavy mineral deposit in the section of Eucla Basin in south east WA.

Astron Ltd's Donald project in the Murray Basin in Vic comprises the Donald (WIM 250) and Jackson (WIM 200) heavy mineral sand deposits. In January 2006, the company reported a total Indicated and Inferred Resource of 693 Mt with a heavy mineral content of 5.1%. Contained within this resource is an Indicated and Inferred Resource of 477 Mt at 1.1% zircon, 1.8% ilmenite, 0.3% rutile and 1.1% leucoxene. The project is planned to be a 7.5 million tonnes per annum (Mtpa) mining operation, producing 500 000 tpa of heavy mineral concentrate for export to China. On 17 March 2009 DMS Pty Ltd, a wholly owned subsidiary of Astron Ltd, reported that it had received provisional Australian Government approval under the Environment Protection and Biodiversity Conservation Act (EPBC) to commence mining the Donald heavy mineral sands deposit. The company continued to work towards obtaining final government approvals to allow it to apply for a mining license and submit work plans.

In September 2009, Diatreme Resources Ltd reported an updated resource for the Cyclone heavy mineral sand deposit amounting to 98.4 Mt at 2.88% heavy minerals, containing 2.8 Mt heavy minerals. The new resource is classified as Measured 11.5 Mt at 3.44% heavy minerals, Indicated 84.4 Mt at 2.82% heavy minerals and only a minor amount of Inferred 2.5 Mt at 2.38% heavy minerals.

In October 2008, Matilda Minerals Ltd, the previous owner of the Tiwi Islands mineral sands mine in the NT, went into voluntary administration and placed its mining operations under care and maintenance. In February 2009, the Tiwi Island mineral sand assets were purchased by Stirling Resources Limited. The Tiwi Island mineral deposits are now held by Matilda Zircon Limited (formerly Olympic Resources Limited) with Stirling Resources holding an 82% interest in Matilda Zircon.

Molybdenum

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Molybdenum (Mo) is used in steels and superalloys to enhance strength, toughness and corrosion resistance. The main commercial source of molybdenum is molybdenite (MoS_2) but it is found also in minerals such as wulfenite ($PbMoO_4$) and powellite ($CaMoO_4$). Molybdenum is mined as a principal ore and is recovered as a by-product or co-product of copper and tungsten mining.

Resources

Australia's Economic Demonstrated Resources (EDR) of molybdenum rose from 198 kilotonne (kt) in 2007 to 224.6 kt in 2008. All the increase in economic resource occurred at Spinifex Ridge in Western Australia (WA). Western Australia is the largest holder of molybdenum resources with about 98% of EDR followed by the Northern Territory (NT) with 1.4% EDR. All EDR is accessible for mining. JORC Code Reserves account for 99% of EDR.

Subeconomic Demonstrated Resources account for about 62% of total Demonstrated Resources. Queensland (Qld) accounts for 75% of subeconomic resources followed by WA with 23% and South Australia (SA) with 2%. In 2008, the Paramarginal Resources increased by about 9% to 101 kt, while the Submarginal Resources decreased from 261.7 kt to 259.7 kt because of resource assessment. Inferred Resources increased by 35% to 664 kt in 2008. WA and Qld account for 60% and 39% of Inferred Resources respectively.

Exploration

The rise in molybdenum price has led to increased molybdenum exploration, which has resulted in resource upgrades for several deposits. Data relating to exploration for molybdenum are not available nationally.

Production

There was no molybdenum production in Australia in 2008.

World Ranking

The distribution of molybdenum resources and production is concentrated in a few countries, with China, the United States (USA), Chile and Canada holding about 88% of the resources. In 2008, world economic resources are estimated to be about 8600 kt based on the United States Geological Survey (USGS) data.

USGS estimates that world production in 2008 amounted to 212 kt of molybdenum which compared with 205 kt in 2007. The USA, China and Chile accounted for about 78% of global outputs in 2008 with USA producing 61.4 kt followed by China with 59.8 kt and Chile with 45 kt.

Industry Developments

The world molybdenum price soared in 2007, reaching a high of US$38 per pound (lb) in September 2008 from a low of about US$5/lb in 2001, but declined sharply from late October 2008 to US$8/lb where it continued through the first quarter 2009.

For almost 20 years the market has been stagnant, but has been transformed as a result of limited supplies and continued strong demand. China's high level of steel production and consumption has

led to strong internal demand for molybdenum. This consumption, together with export quotas, continued to reduce China's molybdenum exports in 2007 and through 2008, thereby supporting the high prices.

In June 2008, Queensland Ores Ltd announced the processing of the first tonne of molybdenum concentrate at its Wolfram Camp tungsten-molybdenum project 90 kilometres (km) west of Cairns in Qld. However, the company suspended operations on 18th November 2008, because of a number of mining and metallurgical issues which impacted on the performance of the treatment plant and the production of the concentrates. The two principal problems were the inability to deliver targeted grade material to the run-of-mine stockpiles, and the inability of the treatment plant to recover an acceptable quality of concentrates from the ore feed. The falling price of molybdenum in late 2008 compounded these issues. In June 2009, Metallic Minerals Limited completed a takeover bid of Queensland Ore Ltd.

In 2008, Moly Mines Ltd signed a 10 year off-take agreement with ThyssenKrupp Metallurgie GmbH for 100% of its molybdenum product from the Spinifex Ridge project in the Pilbara region of WA. The molybdenum concentrate is toll processed to oxide and ferro-molybdenum under an agreement with Molymet at its plant in Santiago, Chile. Moly Mines is reviewing alternative development scenarios for the Spinifex Ridge project, reflecting the recent downturn in world molybdenum prices and the ongoing uncertainty in the international financial and credit markets. Scoping study activities have commenced for the development of an 8-10 million tonnes per annum (Mtpa) operation and processing plant. The project has a combined proven and probable ore reserves of 451 million tonnes (Mt) grading 0.05% Mo and 0.08% Cu.

Thor Mining PLC reported total Proven and Probable Reserves of 2.21 Mt grading 0.47% tungsten oxide (WO_3) and 0.21% molybdenum disulphide (MoS_2) for its Molyhil tungsten-molybdenum project, 250 km north east of Alice Spring in the NT. The company's proposed mine management plan for an open cut operation has been approved by the NT Department of Primary Industry, Fisheries and Mines, subject to placement of a bond for rehabilitation of the proposed mine site.

In 2008, Glengarry Resources Ltd sold its Maitland Cu-Mo deposit west of Townsville in Qld to Kagara Resources. The deposit has a combined Indicated and Inferred Resource of 1.5 Mt grading 1.5% Cu including 115 000 tonnes at 0.17% Mo.

In late 2008, Ivanhoe Australia discovered high-grade molybdenum and rhenium sulphide mineralisation at the Merlin deposit. Molybdenite mineralisation occurs in an east-dipping shear and breccia zone with extremely high-grade portions occurring as a molybdenite-supported breccia. The mineralised intervals are defined in a wedge-shaped body which tapers up-dip and bifurcates into upper and lower zones. The mineralised zone starts at a depth of 100 metres (m) and extends down-dip for more than 400m, with an average width of approximately 25m. The currently identified strike length is 900m. The Merlin deposit, near Cloncurry in northwest Qld, has an Identified Resource of 13 Mt grading 0.8% Mo, and 14 grams per tonne (g/t) rhenium (Re), 0.2% Cu and 4.8 g/t Ag.

Nickel

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

Resources

Australia's Economic Demonstrated Resources (EDR) of nickel increased by 2.3% from 25.8 million tonnes (Mt) to 26.4 Mt in 2008.

Western Australia (WA) remains the largest holder of nickel resources with 90.4% of total Australian EDR. New South Wales (NSW) is the second largest with 6.0%, followed by Queensland (Qld) with 3.3% and Tasmania (Tas) with 0.3%. The EDR in WA comprises both sulphide and lateritic deposits while EDR in NSW and Qld are associated with laterite deposits.

Subeconomic Demonstrated Resources, which accounted for about 4.3% of total Identified Resources, decreased from 5.3% during 2008. The Paramarginal Resources decreased from 1.6 Mt to 1.1 Mt while the Submarginal Resources decreased from 1.1 to 1.0 Mt in 2008. WA has 72.1% of the subeconomic nickel resources.

Inferred Resources decreased by 1 Mt to 20.9 Mt in 2008. WA maintained its dominant share of Australia's Inferred Resources with 89.7% followed by Qld with 5.8%.

The ratio of Inferred Resources to EDR in 2008 was 0.79 to 1.

Accessible EDR

Currently, all nickel EDR is accessible for mining. At the rate of production in 2008, Accessible Economic Demonstrated Resources (AEDR) of nickel are sufficient for 132 years.

JORC RESERVES

About 27% of AEDR comprise Joint Ore Reserve Committee (JORC) Code reserve. The remaining 73% 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 36 years at current rates of production.

Exploration

Expenditure on nickel-cobalt exploration for the 2008 calendar year, as reported by the Australian Bureau of Statistics (ABS), was $324 million, an increase of 29% on 2007. WA attracted most of this expenditure with $303.2 million. Other States with significant nickel-cobalt exploration included Qld, SA and NSW.

Production

Virtually all of Australia's nickel production in 2008 was from WA and amounted to 200 kilotonnes (kt), as reported by the Australian Bureau of Agricultural and Resource Economics (ABARE) and includes production of 2069 tonnes of nickel from the Avebury mine in Tas. The value of all nickel products exported was $7.5 billion. Australia was the world's third-largest producer, accounting for 11.1% of estimated international nickel output.

World Ranking

Based on figures published by the United States Geological Survey (USGS) and the latest Australian resource figures, world EDR of nickel increased by 1.8% to 69.9 Mt in 2008 from 68.7 Mt in 2007. Australia's share of world EDR was 37.7% in 2008. It remained the largest holder of EDR followed by New Caledonia (10.2%), Russia (9.4%) and Cuba (8.0%).

Russia was the largest producer again with 276 kt (16.9%), followed by Canada with 250 kt (15.3%), Indonesia 211 kt (12.9%) and Australia with 200 kt (12.3%).

Industry Developments

The combination of the global financial crisis and falling nickel prices placed a number of nickel mines under financial stress. The two major sulphide nickel mines, owned by BHP Billiton's Nickel West, continued operating at Leinster and Mount Keith. Similarly a number of smaller sulphide nickel operations were continued by Xstrata Nickel Australia Pty Ltd, Mincor Resources NL, Panoramic Resources Ltd, Western Areas NL and Independence Gold NL. Minara Resources NL's Murrin Murrin

lateritic nickel mine also continued to operate. However, OJSC MMC Norilsk closed all four of its sulphide nickel operations and one lateritic nickel mine in 2008 and 2009. Mining was also suspended at the Radio Hill deposit operated by Fox Resources Ltd while the Avebury nickel sulphide mine was placed on care and maintenance by its new owners – China Minmetals Corporation. The most prominent closures were those operated by BHP Billiton – the newly commissioned large Ravensthorpe lateritic mine in WA together with the extended Yabulu nickel refinery in Qld.

NICKEL SULPHIDE DEPOSITS

BHP Billiton's has reported that, its West Australian operations produced 85 900 tonnes of nickel for the 2008 calendar year with most sourced from the Mount Keith and Leinster mines. Production was down from 95 500 tonnes in 2007 due to the Kalgoorlie nickel smelter furnace rebuild and maintenance at the Kwinana nickel refinery.

Most of the nickel ore treated at the Kambalda, Leinster and Mount Keith concentrators, all in WA, is smelted at the Kalgoorlie nickel smelter into nickel matte containing about 68% Ni. The mill and concentrator at Kambalda are supplied with third party ore and produce concentrate containing about 13% Ni. Some of the nickel matte was sold to overseas customers but most of it was refined at BHP Billiton's Kwinana nickel refinery to produce London Metal Exchange (LME) accredited nickel briquettes, nickel powder and other intermediate products such as cobalt-nickel-sulphide. The Kwinana nickel refinery has a capacity of 70 000 tonnes per annum (tpa) of nickel metal.

Mining at BHP Billiton's Cliffs high grade underground mine commenced in mid 2008 with an expected reserve life of five years.

Norilsk Nickel reported production figures for 2008 of 14 805 tonnes Ni metal from the ore mined at Black Swan (WA). Norilsk Nickel's Lake Johnston operations of Emily Ann and Maggie Hays mines (WA) produced 8849 tonnes Ni, and the Waterloo mine, also in WA, produced 5814 tonnes of Ni. Norilsk announced on 16 February 2009 that operations at Black Swan and the Johnston operations (Emily Ann and Maggie Hays) have been suspended; this follows earlier suspension of the Waterloo mine in November 2008.

Xstrata Nickel Australia Pty Ltd completed compulsory acquisition of Jubilee on 31 March 2008.

Xstrata announced in its 2008 Annual Report that metal in concentrates produced from the former Jubilee operations (Alec Mairs, Tapinos, Prospero and Sinclair) for the period commencing 1 February 2008 (the date of the completion of the Jubilee acquisition) to 31 December 2008, totalled 7610 tonnes Ni, 303 tonnes of copper (Cu) and 120 tonnes of cobalt (Co). Total ore milled in the period was 262 857 tonnes. In October 2008, the Sinclair mine commenced operations on schedule and budget and continued ramping up the project towards the end of the year. The concentrates from Sinclair were shipped to the Sudbury smelter in Canada for processing in the fourth quarter of 2008. The company announced in its 2009 half yearly report that it was planning to suspend mining operations at Sinclair nickel mine open cut in October 2009 if nickel prices did not improve. The development of the underground mine at Sinclair was suspended in April 2009.

Western Areas NL nickel mine at the Flying Fox deposit produced 4264 tonnes of Ni in 2008. On 11 May 2009, Western Areas NL and Kagara Ltd executed a Heads of Agreement to enable Kagara's Lounge Lizard nickel deposit, which adjoins the Flying Fox deposit, to be mined using access from Western Area's Flying Fox decline. Total mineral resources at Flying Fox (including Lounge Lizard) are approximately 2.5 Mt averaging 5.5% Ni and containing about 140 000 tonnes of Ni. The company will commence site work in September 2009 at its Spotted Quoll deposit for a two year open cut operation with first production to start in the March quarter, 2010. Spotted Quoll mineral resources are approximately 2 Mt at an average grade of 6.2% Ni of which about 16% of the deposit will be mined by open pit and the rest by underground methods. Western Areas commissioned its Cosmic Boy nickel concentrator in March 2009 but is planning already to upgrade the plant capacity from 300 000 tpa ore to 550 000 tpa by March or April 2010 to treat the ore from Spotted Quoll. The company also reported that the development of the Diggers South and Cosmic Boy deposits will be resumed once the nickel prices stabilise. Western Areas also announced new offtake contracts with BHP Billiton and Jinchuan Group of China for its nickel products.

During 2008, Panoramic Resources Ltd's underground mine operation at Savannah produced 7800 tonnes Ni, 4079 tonnes Cu, and 408 tonnes Co. The Copernicus joint venture mining operation between Panoramic (60%) and Thundelara Exploration Ltd (40%) was suspended in January 2009 and will be restarted once there is a sustained improvement in nickel price. Panoramic acquired the remaining 25% interest in the Lanfranchi mine from its joint venture partner Brilliant Mining Corp in May 2009. In 2008 Lanfranchi (WA) produced 9656 tonnes of Ni and 804 tonnes of Cu. Panoramic announced that in December 2008, its Deacon orebody in the Lanfranchi group contained an Indicated Resource of 2.44 Mt at 2.93% Ni and 0.26% Cu for 71 400 tonnes of contained Ni and 6300 tonnes of contained Cu.

Mincor Resources NL nickel production for 2008 was reported under two groups of operations. The North Kambalda operations comprised the Otter Juan, Carnilya Hill, Coronet and McMahon mines with a combined production in 2008 of 4549 tonnes of Ni, 309 tonnes of Cu and 68 tonnes of Co. The Southern Kambalda operations produced 8624 tonnes of Ni, 791 tonnes Cu and 168 tonnes Co from the Mariners, Miitel and Redross mines. The Miitel mine was placed on care and maintenance in November 2008 and mining was completed at Redross in May 2009, resulting in its closure. During 2008, Mincor carried out a 582 line-kilometre (km), helicopter-borne Versatile Electro-magnetic Survey (VTEM) covering approximately 35 km of prospective basal contact along the Bluebush Line of tenements. The company reported that the survey located 12 high priority electromagnetic anomalies indicative of massive sulphides.

Fox Resources Ltd production from its Radio Hill mine in 2008 in north west WA, amounted to 1140 tonnes Ni and 1776 tonnes Cu. Fox placed the mine on care and maintenance in September 2008 and has embarked on an exploration program to locate additional resources to the south and west of the existing mine workings.

Production from Australian Mines Ltd's Blair nickel mine (WA) in 2008 amounted to 1562 tonnes Ni. The mining operations were suspended on 19 December 2008 as a consequence of low nickel prices and negotiations were commenced for the sale of the mine plant and equipment.

Independence Group NL reported total production for 2008 of 8139 tonnes Ni and 618 tonnes Cu from its Long, Victor South and McLeay mines. In mid 2009, the company reported an Indicated and Inferred Resource of 456 000 tonnes Ni for its newly delineated Moran deposit.

Consolidated Minerals Ltd, owner of the East Alpha, Beta Hunt and the Armstrong mining operations and nickel deposits near Kambalda in WA, was taken over by Palmary Enterprises Pty Ltd in January 2008. Mining operations at the Beta Hunt mine were suspended in December 2008 pending improvement in nickel prices. Production or updated resources figures are not publicly available.

OZ Minerals reported that its Avebury mine produced 2069 tonnes of Ni in 2008, before the mining was suspended on 19 December 2008 due to prevailing low nickel prices. Another 793 tonnes of Ni was produced from stockpiled ore during the March quarter of 2009. Thereafter the mine was placed on care and maintenance and sold to China Minmetals Corporation in mid 2009.

Breakaway Resources Limited reported on 14 April 2008 an Inferred Resource of 600 000 tonnes of ore at 1.39% Ni, 0.3% Cu and 0.5 grams per tonne (g/t) of platinum group elements (PGE) for its recently discovered Horn deposit.

LATERITIC NICKEL DEPOSITS

The annual production for 2008 from the Murrin Murrin lateritic nickel plant (WA), operated by Minara Resources Ltd, amounted to 30 154 tonnes Ni and 2018 tonnes Co. During the year the mining operations were interrupted by loss of gas supplies as a result of a fire at the Apache Energy Varanus Island as well as a planned 12 day shut down. The company stated that, in view of the world recession and consequent contraction in the demand for nickel, it had suspended its heap leach demonstration project after it had produced 1782 tonnes of Ni and 112 tonnes of Co.

OJSC MMC Norilsk Nickel reported an annual production of 4554 tonnes Ni from its lateritic Cawse deposit in WA. The Cawse operation was suspended in October 2008.

The new mine at Ravensthorpe, WA was commissioned in May 2008 but this operation was suspended in January 2009 due to falling nickel prices and weakened demand. Similarly, the extended Yabulu refinery in Qld commenced operations in 2008, but was sold by BHP Billiton in July 2009.

On 30 July 2005, Heron Resources Ltd signed a definitive farm-in and joint venture agreement with Inco Ltd (now Vale Inco Ltd) providing for the potential development of the Kalgoorlie Nickel Project (KNP) in WA. One of the main objectives for Vale Inco in its feasibility studies will be to evaluate whether a plant-scale screen upgrade to 1.5% Ni is achievable. Vale Inco completed a pre-feasibility study on four lateritic nickel deposits of the KNP project and Heron released a summary of the results in February 2009 which stated that the study investigated a project sized for up to 36 tpa of nickel intermediate product with a mine life of 34 years. A high pressure acid leach was considered to be the best leaching technology with Ni and Co extractions of 96% Ni and 93% Cu. Cash operating cost was estimated to be US$4.42 per pound (lb) of nickel (including cobalt credits), and the capital cost was estimated to be US$1.5 billion. Heron reported that it had been advised by Vale Inco in May 2009 that it would not proceed with the full feasibility study for the KNP. Heron entered into a binding Framework Agreement with Ningbo Shanshan Co Ltd with respect to Heron's Yerilla Nickel Cobalt Project. The Agreement provides for Shanshan to undertake a feasibility study into treating ore from the Yerilla project to produce nickel/cobalt concentrate for further processing in China. A 40 tonne bulk sample of Yerilla ore has been shipped to Changsha, China for this work.

In January 2009, Metallica Minerals Ltd updated the lateritic nickel resources of the NORNICO group of lateritic deposits, including Minnamoolka, Bell Creek and the Kokomo deposits, to 50.83 Mt at 0.72% Ni and 0.06% Co with a 0.45% Ni cut-off. In May 2009, Metallica decided to defer its feasibility study on the proposed NORNICO 1 Mt per annum heap leach nickel operation because of the prevailing low nickel prices at the time. Metallica will continue its work on ongoing metallurgical test-work, enhanced process flowsheet development on the NORNICO's key deposits – Bell Creek, Minnamoolka and Kokomo. Deferral of the feasibility will also allow management to include Kokomo in a reactivated NORNICO feasibility study, once market conditions improve.

Metals X completed the first phase of the feasibility study in mid-2008 and confirmed a project concept for the construction of a nickel and cobalt operation producing approximately 40 000 tpa Ni and 3500 tpa Co with an initial mine life of 40 years at an operating costs of less than US$3.50/lb of nickel after cobalt credits. The estimated after tax net present value (NPV) based on a Nickel price of US$20 000, Cobalt price of $45 000 and a US$ exchange rate of 0.85 was $A3.4 billion. Metals X considers that although the overall project returns are lower than they were under the assumptions of the feasibility study, the strong operating returns and positive NPV indications 'demonstrate the credentials of Wingellina as a world class mineral deposit', even under the current depressed economic conditions and the long mine life (approximately 40 years).

In January 2008, Gladstone Pacific Nickel Ltd announced the results of an integrated definitive feasibility study for its proposed mining operation of lateritic nickel at Marlborough (Qld) and for its proposed nickel processing plant at Yarwun, near Gladstone (Qld). The plant is anticipated to process a blend of Marlborough ore (around 30%) with east coast New Caledonian ore (around 70%) to produce about 64 700 tonnes of Ni and 6160 tonnes of cobalt in its first year of production. The first year of full production was expected to be 2015. In mid 2009, the company reported that the global financial crisis may result in significant delays for its project.

Niobium

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

Resources

Australia's Economic Demonstrated Resources (EDR) of niobium was 115 kilotonnes (kt) in 2008. The bulk of the EDR of niobium is associated with the Toongi deposit (Dubbo Zirconia Project) near Dubbo in New South Wales (NSW).

Paramarginal Resources totalling 29 kt accounts for all the subeconomic demonstrated resources and occur in the Toongi deposit. Inferred Resources are estimated to be 811 kt which is unchanged from 2007. WA is the largest holder of Inferred Resources with 85% and NSW holds the remaining 15%.

Accessible EDR

All of Australia's EDR of niobium is accessible.

Exploration

Exploration for niobium is occurring in WA and NSW, but data relating to exploration are not available.

Production

Production of niobium is not reported, but the United States Geological Survey (USGS) reported that one of the leading suppliers of niobium in ores and concentrates into the United States in 2008 was Australia.

World Ranking

Based on world estimates published by the USGS for 2008, the world's largest niobium resources are located in Brazil, which accounts for 2600 kt of the estimated world EDR of 2700 kt. Canada has the second largest EDR with 62 kt, followed by Australia, although data are incomplete for 2008.

Based on USGS figures, world production of niobium in 2008 amounted to 60 kt. The USGS estimates that production was dominated by Brazil with 57 kt in 2008. Canada produced 3 kt.

Industry Developments

In early December 2008, Talison Minerals suspended mining at the world's largest tantalum operations at Wodgina, WA, because of the fall in demand for tantalum metal. Its primary tantalum plant at Greenbushes remains under care and maintenance. Greenbushes' secondary processing plant processes primary tantalum concentrates from the Wodgina mine.

In April 2008, Alkane Resources Ltd commissioned a demonstration pilot plant at ANSTO Minerals at Lucas Heights in Sydney NSW. The plant is producing zirconia concentrate, niobium-tantalum concentrate and yttrium-rare-earth concentrate from the company's Dubbo Zirconia Project in NSW to be shipped to potential customers during 2009.

Phosphate

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Phosphate rock is a general term which refers to rock with high concentrations of phosphate minerals, most commonly of the apatite group. It is the major resource mined to produce phosphate fertilisers for the agriculture sector. Phosphorous also is used in animal feed supplements, food preservatives, anti-corrosion agents, cosmetics, fungicides, ceramics, water treatment and metallurgy. There is no substitute for phosphate.

Australia's commercial resources of phosphate are in northwest Queensland (Qld) at Phosphate Hill, 140 kilometres (km) south east of Mount Isa and on the remote offshore territory of Christmas Island in the Indian Ocean. Phosphate Hill is a world-class rock phosphate resource which is close to the surface and easy to access and mine. The rock is ideal for the manufacture of high analysis mono-ammonium phosphate (MAP) and di-ammonium phosphate (DAP) fertilisers for domestic and international use.

Christmas Island is a source of quality rock phosphate of which approximately 0.7 million tonnes per annum (Mtpa) is exported to the Asia–Pacific region with products used widely in the palm oil sector of the region. Sales of higher-grade rock phosphate are made to Australian manufacturers of MAP fertiliser.

DAP and MAP have different ratios of phosphorous (P) and nitrogen (N), and have slightly different applications. Both products are generally produced as granules with a diameter of between 2-4 millimetres. DAP (20% P and 18% N) is used on broad-acre crops such as cereal, legume, fodder, horticultural and row crops as well as for 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

Excluding Christmas Island resources, Economic Demonstrated Resources (EDR) of phosphate rock is 81.6 million tonnes (Mt), which is unchanged from 2007. There is no publicly available information on phosphate rock resources for Christmas Island. All EDR is sedimentary phosphate rock (phosphorites) from Phosphate Hill in Qld and has an average grade of about 24% P_2O_5. All EDR is accessible for mining and account for 100% Joint Ore Reserve Committee (JORC) Code reserves.

About 86% of Australia's total demonstrated resources of 997 Mt occur in the Georgina Basin in Qld and are classified as paramarginal. The remaining 14% of demonstrated resources occur in Western Australia (WA) within carbonatite at Mount Weld 26 km southeast of Laverton, and at Balla Balla magnetite deposit 100 km west-south-west of Port Hedland.

About 83% Australia's inferred phosphate resources which total 1574 Mt occur as phosphorites in the Georgina Basin. These resources are distributed between Qld and the Northern Territory (NT). The remaining 17% occur in WA mainly associated with the Mount Weld deposit.

Exploration

There is renewed interest in phosphate rock exploration especially in Qld, the NT and WA although specific data relating to phosphate rock exploration are not available.

Production

There are two main locations for the production of phosphate rock, Phosphate Hill (Qld) and Christmas Island. Several small operations near Bendleby in South Australia are mainly used in domestic industrial applications.

The Queensland Department of Mines and Energy estimates that Incitec Pivot's production from Phosphate Hill in 2007-08 amounted to 2.154 Mt of phosphate rock (compared with 2.129 Mt in 2006-07). Phosphate Resources Ltd's production figures for Christmas Island operations in 2008 are not available because of commercial-in-confidence considerations.

World Ranking

The United States Geological Survey (USGS) estimated that total world resources are 15 000 Mt. Australia's EDR of phosphate rock comprises less than 1% of the world's resources. Morocco and Western Sahara (combined) hold about 38%, followed by China with 27%, South Africa with 10% and the USA with 8%.

World production totalled 167 Mt in 2008, with China producing 50 Mt, the USA 30.9 Mt and Morocco and Western Sahara 28 Mt. USGS estimates that, excluding Christmas Island, Australia produced 2.3 Mt in 2008.

Industry Developments

Phosphate rock prices rose strongly during 2008 reaching around US$450 a tonne by mid year as a result of the increasing global demand for fertiliser for food production and for biofuel crops. However, by early 2009 it had retracted substantially to US$110 a tonne, which is still double the long

term price. The dramatic decrease was a result of the global financial crisis which had a significant influence on phosphate demand and pricing.

Incitec Pivot announced plans to expand Phosphate Hill (Qld) production capacity from 970 kilotonnes per annum (ktpa) to 1.01 Mtpa, to be completed in 2010.

Legend International Holdings Inc. (Legend) is developing a 3 phase phosphate operation in Qld, based on phosphate rock deposits north west of Mount Isa, most notably at Lady Annie, Lady Jane, D-Tree, Lily Creek and Sherrin Creek within the Georgina Basin. In July 2008, the company signed an off-take agreement with the Indian Farmers Fertiliser Co-operate (IFFCO) for the purchase of up to 5 Mtpa. Legend plans to commence shipping by rail 0.5-1 Mtpa DSO grading 30-34% phosphate by 2010 through the Port of Townsville and ramping up to 5 Mtpa by 2013. The company is to undertake studies into producing value added fertiliser products, MAP and DAP, for domestic and international use.

GBM Resources Ltd is investigating phosphate resources at its Bungalien project (Qld), located 50 km north of the Incitec Pivot-owned Phosphate Hill deposit.

Korab Resources Limited has completed a scoping study on the GeolSec rock phosphate deposit located near Rum Jungle 65 km south of Darwin in the NT. The study indicated that the deposit could be developed as a simple quarrying operation capable of supplying the agricultural sector with a ground-up rock phosphate to be used as an organic fertiliser. The company is planning an initial production in 2010 of 10 ktpa and increasing to 30 ktpa by 2013.

Phosphate Australia Limited is undertaking pre-feasibility studies on its Highlands Plains project (NT) where it has reported Inferred Resources of 56 Mt at 16% P_2O_5 at a cut-off grade of 10%. The company is targeting a higher grade zone, Western Mine Target Zone, containing 7 Mt at 23% P_2O_5 with a 20% P_2O_5 cut-off grade occurring at a shallower depth. The company is aiming for a 500 ktpa operation commencing in late 2011.

Minemakers Ltd has commenced a feasibility study in the NT into its Wonarah phosphate project in the Georgina Basin. The company plans to develop a high-grade open cut mine producing direct shipping ore (DSO) material at a grade of more than 36% P_2O_5. A further resources assessment has established a resource of 1105 Mt grading 18% P_2O_5 including 167 Mt at 21.3% P_2O_5 in the Indicated Resource category. This proposed development less than 300 km from the Darwin to Adelaide railway would utilise established road, rail and port infrastructure. In early 2009, Minemakers Ltd and the Darwin Port Corporation signed a Heads of Agreement covering the shipment of rock phosphate through the existing port facilities. The DSO production is planned to commence in mid 2010 with exports of 3 Mtpa of beneficiated phosphate rock scheduled from 2011.

Navigator Resources Limited reported Inferred Resources of 3.55 Mt at 2% rare earth oxide (REO), 11.2% P_2O_5, 216 parts per million (ppm) U_3O_8 and 36 ppm thorium at its Cummins Range carbonatite deposit in the southeast part of the Kimberley region in WA. Within the deposit, the company reported a higher grade phosphate zone, which partially overlaps an REO zone, of 13.1 Mt at 10.0% P_2O_5.

Aurox Resources Limited is continuing studies into the beneficiation of phosphate from its Balla Balla project in WA, which has a total phosphate resource of 89.69 Mt grading 3.74% P_2O_5. The phosphate mineralisation extends to 20 metres above the titanomagnetite ore into the hanging wall waste rock. The apatite bearing material displays grades of between 3% and 7%. The company is aiming to produce 1 Mtpa of plus 30% P_2O_5 concentrate.

On Christmas Island, Phosphate Resources Ltd shipped a record 262.3 kilotonnes (kt) of phosphate for the September 2008 quarter, an increase of 35 kt over the September 2007 quarter. However, from late October the global financial crisis forced the company to have an unscheduled shutdown of the Christmas Island operations for the remainder of the year. Following a successful appeal in the Federal Court of Australia setting aside a Ministerial decision refusing the company approval for expanded mining on the island, Phosphate Resources Ltd has reapplied to the Australian government

to explore and mine an additional eight areas comprising a total of 256 hectares, extending phosphate operations from 5 years up to 12 years.

Platinum Group Elements

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The platinum group elements (PGE) comprise platinum (Pt), palladium (Pd), iridium (Ir), osmium (Os), rhodium (Rh) and ruthenium (Ru). The elements of most commercial significance are Pt, Pd and to a lesser degree, Rh. The properties of PGEs of commercial importance are their resistance to corrosion and oxidation, high-melting points, electrical conductivity and catalytic activity in the chemical, electrical, electronic, glass and automotive industries. The emerging commercial importance of PGEs is in the applications related to the motor vehicle industry as a result of increasing global emission controls, development of lead-free petrol and efforts to improve fuel efficiency. Other applications include the use of platinum-rhodium alloys to oxidise ammonia to nitric acid in the production of fertilisers while platinum is also used extensively in jewellery.

According to figures published by Matthey (2008)[2], the main demand for platinum in 2007 was autocatalyst applications (60%) and jewellery manufacture (23%). The main demand for palladium was also in autocatalyst (65%), electronic (19%) and jewellery production (11%).

Resources

Australia's Economic Demonstrated Resources (EDR) of PGEs decreased by 1% from 19.1 tonnes to 18.9 tonnes in 2008.

Western Australia (WA), New South Wales (NSW) and the Northern Territory (NT) hold all of Australia's resources of EDR. However the EDR of PGEs in individual deposits is often unrecorded so that the full distribution of the PGE EDR between the states is unknown.

In 2008, the Paramarginal Resources decreased from 119 tonnes to 118.5 tonnes while the Submarginal Resources remained the same at 35.3 tonnes. Virtually all of the Paramarginal Resources, 99.8%, and all of the Submarginal Resources are in WA.

Inferred Resources increased during 2008 from 135 tonnes to 145.3 tonnes. WA had most of these resources at 86.6%, NSW with 11% and NT with 2.3%.

Total Identified Resources of PGEs, that is EDR plus Paramarginal, Submarginal and Inferred, total about 318 tonnes. Of this amount, deposits which have only PGE resources amount to about 205 tonnes or around 64%, although all of Australia's production is as by-product from PGE resources associated with nickel sulphide deposits in WA.

Accessible EDR

Currently, 14.6 tonnes of the PGE EDR is accessible for mining while the balance of 4.3 tonnes occurs within national parks.

JORC Reserves

About 1% of Accessible Economic Demonstrated Resources (AEDR) of PGEs comprise Joint Ore Reserve Committee (JORC) Code reserve. The remaining 99% 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. The reason for the low Reserve figure is that many companies don't report the PGE content in their nickel reserves.

2 Mathey, J. 2008 Platinum 2008. Johnson Matthey Public Limited Company. Precious Metals Marketing. http://www.platinum.matthey.com/uploaded_files/Pt2008/08_complete_publication.pdf

Exploration

Expenditure for PGEs is not reported separately and much of the PGE resources are associated with nickel deposits. Areas of activity in 2008 where PGEs were a significant component of exploration targets included the West Musgrave in the WA, NT and SA border region of central Australia along with the WA regions in the eastern goldfields of the Yilgarn, the East Kimberley and West Pilbara.

Production

All of Australia's PGE (palladium (Pd) + platinum (Pt)) production in 2008 was as by-product of nickel mining in WA and amounted to 0.71 tonne, as reported by the WA Department of Mines and Petroleum at a value of $8.75 million. There is no publicly available record of PGE production from individual mines. Australia was a very minor producer compared with South Africa with 233 tonnes Pd+Pt (57.4%), Russia 103 tonnes (23.4%) and Canada 19.7 tonnes at (4.9%).

World Ranking

Based on figures published by the United States Geological Survey (USGS) and the latest Australian resource figures, world EDR of PGE was unchanged at 71 000 tonnes in 2008. Australia's share of world EDR was 0.03% in 2008. South Africa has by far the largest share of the world's EDR with 63 000 tonnes (88.7%) followed by Russia with 6200 tonnes and USA with 900 tonnes (1.3%).

Industry Developments

About two thirds of Australia's Identified Resources of PGE are in the following deposits in which PGE is the major commodity

- **Munni Munni,** WA – published Measured, Indicated and Inferred Resources of 23.6 million tonnes (Mt) at 1.5 grams per tonne (g/t) Pd, 1.1g/t Pt, 0.1g/t Rh, 0.2g/t gold (Au), 0.09% nickel (Ni), and 0.15% copper (Cu). In June 2009, Platina Resources Limited reported that it was reviewing its Munni Munni project with a focus of a smaller project with scope for selective mining and recent metallurgical advances suited for small-scale processing.
- **Panton,** WA – 14.3 Mt at 2.19g/t Pt, 2.39g/t Pd, 0.31g/t Au, 0.27% Ni, and 0.07% Cu. Platinum Australia Limited reported in its 2008 Annual Report that its Panton project is on hold pending improvement in PGE prices.
- **Fifield,** NSW – published Inferred Resources amount to 10.2 Mt at 0.61g/t Pt, 2 Mt at 0.18% cobalt (Co) and 0.35% Ni. Historical production from this deposit amounted to about 640 kilograms (kg) of PGEs. The deposit is held by Platina Resources Limited – but no significant activities were reported in regard to PGEs in 2008.
- **Weld Range – Parks Reef** PGE (with minor Au) deposit, WA - a published Inferred Resource amounted to 14.76 Mt at 1.1g/t Pt+Pd+Au which occurs in a truncated lateritic profile overlying low-grade primary PGE mineralisation in ultramafic rocks[3] The Weld Range PGE deposit is near the very large Weld Range lateritic nickel-cobalt deposit which has an Inferred Resource of 330 Mt at 0.75% Ni and 0.06% Co. Dragon Mining Limited announced in September 2009 that its wholly owned subsidiary had entered into an agreement to acquire 100% interest in the Weld Range tenements covering the lateritic nickel-cobalt deposit and the separate PGE dominant deposit.

PGE resources are present also in deposits where other commodities are dominant, mainly komatiitic nickel-cobalt sulphide deposits as well as lateritic nickel deposits. They include:

- **Radio Hill** nickel mine, WA – Fox Resources Ltd reported that remaining Indicated and Inferred Resources of palladium amounted to 1.275 Mt at 0.493g/t. Details are not available on production of palladium in 2008. Fox Resources updated the nickel and copper resources for the Radio Hill deposit in September 2009, but no details were given for palladium content. The mine is currently on care and maintenance.

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3 Parks, J, 1998. Weld Range platinum group element deposit. In: Geology of Australian and Papua New Guinean Mineral Deposits (eds: Berkman, D.A. & Mackenzie, D.H.), The Australasian Institute of Mining and Metallurgy: Melbourne, 279–286.

- **Waterloo** nickel mine, WA – the resources for this deposit were last reported in 2004 as 653 000 tonnes at 2.795% Ni, 0.194% Cu and 0.858g/t PGE. Recorded production amounts to 185 000 tonnes at 2.76% Ni in 2007 and 57 818 tonnes Ni in 2006 with no details given on production of PGEs. The mine's owner, OJSC MMC Norilsk Nickel, placed the mine on care and maintenance in November 2008 because of prevailing low nickel prices and reduced world demand.
- **Nyngan** lateritic nickel-cobalt-scandium-platinum deposit, NSW – Jervois Mining Limited reported in June 2005, a resource of 16 Mt at 0.87% Ni, 0.06% Co of which there is 3 Mt at 290 parts per million (ppm) scandium (Sc) and 0.22g/t Pt. The scandium-rich portion of this deposit was updated in June 2009 as Measured Resources of 2.718 Mt at 274ppm Sc and Indicated Resources of 9.294 Mt at 258ppm Sc.
- **Wildara** nickel sulphide deposit, WA – the resources for this deposit were announced by Breakaway Resources Limited in April 2008 as 600 000 tonnes at 1.39% Ni, 0.3% Cu and 0.5g/t PGE.
- **The Horn** nickel sulphide deposit, WA – in April 2008, Breakaway Resources Limited reported a small Inferred Resource for their Horn nickel deposit of 600 000 tonnes at 1.39% Ni, 0.3% Cu and 0.5g/t Pd+Pt. In early 2009, Breakaway reported that massive and matrix nickel sulphide mineralisation at the Horn deposit has been drilled over a 500 metre strike length and remains open along strike. Geological mapping undertaken during the March quarter of 2009 has confirmed the presence of nickeliferous gossans within a structurally bound, high-MgO ultramafic unit immediately south of the known mineralisation.
- **Yarrawindah Brook**, WA – an Inferred Resource of 2.9 Mt at 0.79g/t PGE was announced by Washington Resources Ltd in March 2006. The company continued exploration in this region during 2008.

Other PGE deposits with recorded resources which have had historic interest but did not record exploration or assessment activity in 2008 include:

- **Nebo-Babel** nickel-copper-PGE deposit, WA – a news article in The West Australian newspaper, dated 10 February 2007 reported that the Nebo-Babel nickel-copper-PGE deposit, discovered by Western Mining Corporation in mid-2000 has a preliminary resource of 393 Mt grading 0.3% Ni, 0.3% Cu and 0.18g/t PGE. The deposit was later acquired by BHP Billiton Limited as a result of its takeover of Western Mining Corporation in mid-2005.
- **Syerston** lateritic nickel-cobalt-platinum deposit, NSW – in April 2000, Black Range NL announced a total platinum resource of Measured, Indicated and Inferred Resources of 108.3 Mt at 0.21g/t Pt which occurs partly within the Syerston nickel-cobalt deposit.
- **Coronation Hill**, Kakadu National Park, NT, - the Coronation Hill deposit has an Inferred Resource of 6.69 Mt at 6.42g/t Au, 1.01g/t Pd and 0.3g/t Pt which was reported in 1990. The deposit occurs within the Kakadu National Park and is inaccessible for mining.
- **Thomson River**, Victoria – in 1981 CRA Exploration Pty Ltd estimated resources as 40 000 tonnes averaging 3.2g/t Pt, 3.6g/t Pd, 2.7% Cu, 9.5g/t Ag and 2.5g/t Au. Intermittent mining since the discovery of the deposit about 1864 produced around 13 200 tonnes of ore, from which only about 10 kg of Pt was extracted.

Rare Earths

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Rare earths are a group of 15 elements with atomic numbers ranging from 57 to 71. In order of their respective atomic numbers the elements are: lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu). Two other elements, scandium (Sc) and yttrium (Y), are commonly classed as rare earths because of their natural association with rare earths.

The demand for rare earth elements (REE) is forecast to maintain a strong growth from the current level of around 124 000 tonnes per annum (tpa) rare earth oxide (REO), which has an estimated

value of US$1.5 to $2 billion, to about 200 000 tpa in 2015. The most significant increases in demand are attributed to a predicted expansion in hybrid cars, followed by petroleum catalyst, glass manufacturing and polishing and multi-level electronic components. The smallest sector by volume, but largest by value, are europium and terbium which are used in the production of phosphors for televisions and energy efficient light globes.

The main consumers of rare earths are China, the USA, Japan, Korea and Thailand with China reportedly accounting for about 60% of the world's consumption. The Chinese government has imposed production and export restrictions, adding upward pressure on prices for rare earths and contributing to incentives for development of rare earth resources outside China.

Resources

Geoscience Australia's latest estimate of Australia's rare earths reported as REO amounted to 1.65 million tonnes (Mt) of economic demonstrated resources (EDR), 0.36 Mt paramarginal and 34.3 Mt in the submarginal resource categories. There is a further 20.17 Mt in the inferred resources category. About 49 Mt of the submarginal and inferred resources are in the Olympic Dam iron oxide-copper-gold deposit (predominantly 0.2% La and 0.3% Ce) and are not currently economic. Small quantities of scandium (3140 tonnes paramarginal and 770 tonnes inferred Sc), commonly included with rare earths, were also reported. In addition, about 4160 tonnes of paramarginal resources and 51 980 tonnes of inferred resources were reported as rare earth elements (REE).

Very significant resources of rare earths are contained in the monazite component of heavy mineral sand deposits, which are mined for their ilmenite, rutile, leucoxene and zircon content. Monazite is a rare earth-thorium phosphate mineral found within heavy mineral sand deposits in Australia. Using available information, Geoscience Australia estimates Australia's monazite resources to be in the order of 6.2 Mt. Assuming an REO content of monazite to be about 60%, the heavy mineral deposits could hold an REO resource in the order of 3.72 Mt. Currently, extraction of rare earth from monazite is not viable because of the cost involved with the disposal of thorium and uranium present in the monazite.

Production

Mining operations commenced at the Mt Weld deposit in Western Australia (WA) in 2007 and around 98 000 cubic metres of ore has been stockpiled pending the completion of a concentration plant at the mine site. There has been no recorded production of REO in Australia during 2007 or 2008.

Globally, the production and resources of rare earths is dominated by China, which accounts for about 97% of the production followed by India with about 2%. These figures are only approximate because the production for the Commonwealth of Independent States, which is made up of former members of the Soviet Union, is not available.

World Ranking

China holds 27 Mt (32%) of the EDR for REO, followed by the Commonwealth of Independent States 19 Mt (22.5%) and the USA with 13 Mt (15.4%). Australia accounts for 1.98% of world EDR with 1.65 Mt REO.

The main types of REE deposits make up the largest REO resources in the world with the Bayan Obo deposit in China, which is predominantly REE-iron ores with bastnasite and monazite as the main REE bearing minerals, totalling at least 48 Mt REO at a grade of 6%. The only production of REOs from a carbonatite has been from the Mountain Pass deposit in California, which has total resources of 1.8 Mt REO at an average grade of about 9% REO. Deposits associated with carbonatite laterites include Araxa in Brazil with 8.1 Mt REO at 1.8% and Mt Weld in WA with 1.74 Mt REO at 9.7%. Other deposit categories include a vein type at Nolans Bore in the Northern Territory (NT) and an alkaline trachyte deposit at Toongi in New South Wales (NSW) along with a peralkaline syenite deposit at Lovozero in Russia.

Industry Developments

Lynas Corporation Ltd: The company started mining the Mt Weld deposit, which is a laterite over alkaline carbonatite complex, in WA in 2007 and by early 2008, the measured (2.21 Mt at 14.7% REO), indicated (3.84 Mt at 11.5% REO) and inferred resources (6.19 Mt at 6.8% REO) totalled 12.2 Mt at 9.7% REO with an REO content of 1.18 Mt. In another part of the carbonatite complex there are indicated (1.5 Mt) and inferred (36.2 Mt) resources totalling 37.7 Mt, which include total lanthanides at 1.16% and 0.09% Y_2O_3. The company completed the first stage of mining activities and commenced construction of a concentration plant at Mt Weld and an advanced materials plant in Malaysia. Both of these activities were suspended in the first quarter of 2009 because of uncertainty concerning the financing arrangements for the project. In May 2009, Lynas Corporation and China Non-Ferrous Metal Mining (Group) Co Ltd (CNMC) signed a binding heads of agreement for CNMC to become a majority shareholder in Lynas. Total capital provision to Lynas will be more than $500 million. It will take US$286 million to complete and commission the 1st phase of the rare earths project to produce 10 500 tonnes per annum (tpa) REO and an estimated US$80 million for the 2nd phase of the project to bring production to 21 000 tpa REO. The transaction is subject to specified conditions, including Australian and Chinese regulatory approvals, as well as Lynas shareholder approval.

Arafura Resources Ltd: Nolans Bore rare earth-phosphate-uranium-thorium deposit is located 1 35 km north west of Alice Springs in the NT, and has a measured, indicated and inferred resources totalling 30.3 Mt to a depth of 130m which grades at 2.8% REO, 12.9% P_2O_5, 0.44 lbs/tonne U_3O_8, and 0.27% Th. In February 2009, Arafura announced it had executed a letter of intent with the Jiangsu Eastern China Non-Ferrous Metals Investment Holding Co Ltd (JEC) a subsidiary of the East China Mineral Exploration and Development Bureau (ECE). Under the terms of the letter of intent, ECE can acquire up to 25% of the issued capital of Arafura through two share placements. The transaction is subject to a number of conditions precedent including the approval by Australian and Chinese regulatory authorities, appropriate due diligence sign-off and ultimately shareholder approval. The funds will be used to progress Nolans bankable share placement. The company is currently conducting a definitive feasibility study on the Nolans Bore project.

Alkane Resources Ltd: The company's Dubbo Zirconia Project located 30 km south of Dubbo in NSW has a reported measured resource of 35.7 Mt and 37.5 Mt of inferred resources grading 1.96% ZrO_2, 0.04% HfO_2, 0.46% Nb_2O_5, 0.03% Ta_2O_5, 0.14% Y_2O_3, 0.745% total REO, 0.014% U_3O_8, and 0.0478% Th.

A Demonstration Pilot Plant (DPP) was constructed and commissioned in May 2008 at the Australian Nuclear Science and Technology Organisation (ANSTO), Lucas Heights. The DPP is designed to test the flowsheet and provide the various products for distribution to potential end users. Alkane reported that the DPP completed two trial runs in 2008 and one more in the first quarter of 2009. The plant operated efficiently during this period with no significant issues and in the latter half of the run produced high quality zirconium and niobium products.

Navigator Resources Ltd: The company's Cummins Range carbonatite deposit occurs in the south east part of the Kimberley region in WA. In March 2008 it reported inferred resources of 3.55 Mt at 2% REO, 11.2% P_2O_5, 216 parts per million (ppm) U_3O_8 and 36 ppm Th.

Historic exploration records reported that the Yangibana ferrocarbonatite-magnetite-rare earth-bearing dykes (ironstones) form part of the Gifford Creek Complex in WA. The dykes occur as lenses and pods, are typically the last stage of carbonatite fractionation and are enriched in REEs, fluorite and U-Th mineralisation. The Yangibana prospect has a recorded resource of 3.5 Mt at 1.7% REO. The rare earths are in coarse grained monazite containing up to 20% Nd_2O_5 and 1600 ppm Eu_2O_3.

Other deposits of possible significance for rare earth resources in the future include the BHP Billiton's Olympic Dam iron oxide-copper-gold deposit and the Mt Gee Marathon Resources uranium rare-earth deposit in SA.

Shale Oil

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Oil shale is organic-rich shale, which yields substantial quantities of oil (normally referred to as shale oil) and combustible gas by heating (retorting) and distillation. The organic material in oil shale is called kerogen, which under appropriate conditions in the Earth's crust can be a precursor to conventional oil reservoirs. One tonne of commercial grade oil shale may yield from about 100 to 200 litres (L) of oil.

Resources

Oil shales of commercial interest are predominantly in a series of narrow and deep extensional-basins near Gladstone and Mackay in central Queensland (Qld). These are thick Tertiary lacustrine (lake-formed) deposits which are relatively easy to mine and process compared to carbonate-rich oil shales (marls) elsewhere in the world. The Permian Galilee and Bowen Basins in Qld contain oil shale associated with coal measures. Oil shales occur in the Cretaceous Toolebuc Formation of the Eromanga Basin in north west Qld. Minor deposits are located in northern Tasmania (Tas) (Latrobe tasmanite deposit), Eyre Peninsular in South Australia (SA) and an oil shale – heavy mineral sand deposit in southern Western Australia (WA).

Resource estimates were reviewed to take into account the historical nature of the estimates and losses resulting from processing. Australia's shale oil resources estimates are for **recoverable** shale oil. Paramarginal and Submarginal Demonstrated Resources of shale oil are 213 Gigalitres (GL) (1340 million barrels) and 2074 GL (13 050 million barrels) respectively. This could increase significantly if research and development into processing shale oil results in the development of a commercial plant.

An Inferred Resource is estimated to amount to 1272 GL (8000 million barrels). This figure excludes the 'total potential' shale oil resources of the Toolebuc Formation of around 245 000 GL estimated by Geoscience Australia's predecessor, the Bureau of Mineral Resources, and the CSIRO in 1983[4]. The research project undertook detailed geological, petrophysical and geochemical examination of the oil shales of the Toolebuc Formation. The objectives of the project included investigating and developing methods to assist government and industry to assess the potential of the sedimentary sequence as a possible future source of oil shale and developing an understanding of geological controls and the distribution of oil shale within the Toolebuc Formation. A resource assessment of around 245 000 GL was based on a productive oil shale covering an area of 484 000 km^2 that ranges in thickness from 6.5 to 7 metres (m), has a specific gravity of 1.9, and yields an average 37 L of oil per tonne.

Exploration

Exploration is predominantly focused near Gladstone and Mackay in central Qld and in north west Qld. South east of Devonport in Tas, Boss Energy Ltd is continuing to undertake exploration work to define the resource extent of the Latrobe oil shale deposit. Data associated with shale oil exploration are not available.

Production

There is no oil being extracted from oil shale in Australia. From 2000 to 2004, the Stage 1 demonstration-scale processing plant at the Stuart deposit near Gladstone in central Qld produced more than 1.5 million barrels of oil using a horizontal rotating kiln process (Alberta Taciuk Process). No oil has been produced since 2004. The facility is currently being dismantled.

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4 Ozimic, S. and Saxby, J.D., 1983. Oil Shale Methodology: An examination of the Toolebuc Formation and the laterally contiguous time equivalent units, Eromanga and Carpentaria Basins. Bureau of Mineral Resources and CSIRO research project.

The demonstration plant achieved stable production capacity of 6000 tonnes of shale per day and oil yield totalling 4500 barrels per stream day while maintaining product quality and adhering to Environment Protection Authority emissions limits. The oil products from the demonstration plant were Ultra Low Sulphur Naphtha (ULSN) 55% to 60% and Light Fuel Oil (LFO) 40% to 45%.
The ULSN, which can be used to make petrol, diesel and jet fuel, has a sulphur content of less than 1 part per million (ppm). To put this into perspective, from January 1, 2008, the regulated maximum content of sulphur in premium unleaded petrol will be reduced from 150ppm to 50ppm.

World Ranking

The 2007 Survey of Energy Resources by the World Energy Council (WEC) reported that total world resources of shale oil are estimated at 2.8 trillion barrels (around 550 000 GL). The largest known deposit is in the western United States (2.6 trillion barrels), with other important deposits in the Russian Federation, the Democratic Republic of the Congo, Brazil, Italy, Morocco, Jordon, Australia and Estonia. Only Estonia, China and Brazil produce shale oil. The same WEC survey reported that total oil production for 2005 was 859 ML, with Estonia producing 433 ML, China 226 ML and Brazil at 200 ML.

Industry Developments

In November 2008, Qld Government amendments to the ***Mineral Resources Act 1989 (Qld)*** placed a 20-year moratorium on oil shale mining in the Whitsunday region around Proserpine. Existing exploration leases remain, but the grant of new tenures and a variation of existing entitlements has been suspended pending the review of the desirability of oil shale exploitation.

In August 2008, the Qld Premier announced two years of research into whether oil shale deposits can be developed in an environmentally acceptable way. A report is due by August 2010.

In Qld, companies have either scaled back investment or projects are under review, these include:

- Queensland Energy Resources Ltd (Stuart Project, Qld): construction of a small-scale technology demonstration plant using Paraho vertical shaft kiln processing system.
- Blue Ensign Technologies Ltd (Julie Creek Project (south), NW Qld): testing of the thermal solution technology (Rendall Process), a thermal conversion and hydrogenation followed by supercritical solvent extraction and designing a demonstration plant.
- Greenvale Mining NL (Alpha project, Qld): reviewing the viability of Vertical Retort Torbanite (VRT) processing technology being developed by a South African based company.
- Xtract Energy Plc (Julie Creek Project (north), NW Qld): developing Xtract technology, a hydrogen and supercritical solvent extraction process.

Boss Energy Ltd is reviewing treatment processes of tasmanite oil shale at its Latrobe project, northern Tas.

Tantalum

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The main use of tantalum is in the manufacture of capacitors required for the electronics and telecommunications industries. Due to their small size and high reliability, these capacitors are used in miniaturised electronic circuits, mainly in mobile phones. Tantalum metal is also used in the chemical industry for its anti-corrosive properties, as tantalum carbide in tools for metal cutting and machining, and in metal alloys in the aerospace and electricity-generating industries. Overall, approximately 60% of annual world consumption of tantalum is used in the electronics industry, with more than half of this currently being used in the manufacture of mobile phones.

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

Australia, through the mining operations at Greenbushes 250 kilometres (km) south of Perth, Western Australia (WA) and Wodgina 100 km south of Port Hedland WA, was the world's largest producer of tantalum (in tantalum concentrates) in 2008, producing almost half of the world's mine output. However, tantalum production from these mines was suspended in December 2008 (refer 'Industry Developments')

Resources

In WA, granitic rare-metal pegmatites are the dominant host rock for primary tantalum mineralisation. The only exceptions are the carbonatite type at Mount Weld deposit in the eastern goldfields, WA, and an unusual form of subalkaline granite–syenite mineralisation at the Brockman deposit, south east of Halls Creek, WA.

Australia's Economic Demonstrated Resources (EDR) are estimated to be 51 kilotonne (kt) of tantalum in 2008, 21% increase on 2007. All tantalum EDR are accessible for mining. Approximately 37% of EDR comprises JORC Ore Reserves as reported by industry. Subeconomic Demonstrated Resources account for about 24% of total Demonstrated Resources. The Paramarginal and Submarginal Resources amount to 15 kt and 0.3 kt, respectively. Inferred Resources are estimated to be 80 kt. WA is the largest holder of tantalum with 88% of total Demonstrated Resources while New South Wales (NSW) accounts for 12%.

Exploration

Data relating to exploration for tantalum are not available.

Production

In 2008, production of tantalum was estimated to be 680 tonnes an increase of about 26% over 2007. All production was from the Wodgina mine where the ore is crushed at a primary plant before being transported to Greenbushes mine for secondary processing and upgrading to a final product.

World Resources and Production

Based on estimates published by the United States Geological Survey (USGS), the world total resources amount to 130 kt of tantalum in 2008. The world's largest tantalum resource holder is Brazil with an estimated 88 kt, followed by Australia with 51 kt.

World production of tantalum in 2008 was estimated by Geoscience Australia (using WA Department of Mines and Petroleum and USGS data) to be 1.058 kt, an increase of about 15% on 2007. Production in 2008 was dominated by Australia, with 680 tonnes, which amounted to about 64% of world output, although this figure is not complete for 2008. According to the USGS, other main producers were Brazil with 180 tonnes, followed by Ethiopia (77 tonnes), Canada (45 tonnes), and Rwanda (42 tonnes).

Industry Developments

In December 2008, Talison Minerals suspended mining at Wodgina WA, the world's largest tantalum producer, because of a fall in demand for tantalum metal and an increase in the supply of tantalum from Central Africa, mainly the Democratic Republic of Congo where it was produced by indigenous people using artisan type mining methods, some of which were illegal operations.

Talison Minerals' Greenbushes operations consist of an open pit, underground mine, primary and secondary tantalum processing plants, tin smelter and a lithium plant. Greenbushes open pit mining operations continued during the year and the secondary processing plant processed primary tantalum concentrates from Wodgina mine. The primary tantalum plant at Greenbushes remained under care and maintenance.

In April 2008, Alkane Resources Ltd commissioned a demonstration pilot plant at ANSTO Minerals at Lucas Heights in Sydney NSW. The plant is producing several tonnes of zirconia concentrate, niobium-tantalum concentrate, and yttrium-rare-earth concentrate from the company's Dubbo Zirconia Project in NSW to be shipped to potential customers during 2009.

Thorium

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Thorium oxide (ThO_2) has one of the highest melting points of all oxides (3300°C) and has been used in light bulb elements, lantern mantles, arc-light lamps and welding electrodes as well as in heat resistant ceramics.

Currently there is no large scale demand for thorium resources. Thorium can be used as a nuclear fuel through breeding to U^{233} and any large-scale commercial demand for thorium can be expected to be dependant on the future development of thorium fuelled nuclear reactors. Several reactor concepts based on thorium fuel cycles are under consideration, but a considerable amount of development work is required before it can be commercialised.

India has been developing a long-term nuclear fuel cycle to utilise its abundant thorium resources. The program consists of three stages whereby:

- In stage 1, plutonium is produced in pressurised heavy water reactors fuelled by natural uranium and in light water reactors,
- In stage 2, the nuclear fuel in fast neutron reactors will consist of a blanket of uranium and thorium around a core of plutonium derived from stage 1. The plutonium is burned to breed U^{233} from thorium, and more plutonium is produced from the uranium in the blanket.
- In stage 3 Advanced Heavy Water Reactors (AHWRs) burn the U233 and plutonium with thorium to derive about two thirds of the power from thorium.

The construction of a 500 megawatt electric (MWe) prototype fast breeder reactor has commenced at Kalpakkam and the unit is expected to be operating in 2011. This project will take India's thorium program to stage 2.

Early in April 2008, India commissioned an AHWR critical facility designed to conduct experiments to validate reactor physics for a 300 MWe technology demonstrator thorium-fuelled AHWR. However, full commercialisation of the AHWR is not expected before 2030.

On 6 March 2009 it was reported in the Chennai Times that the demonstration 300 MWe AHWR project is under review by a regulatory board and concurrence is expected to be received by next year. Once the concurrence is given it would take at least seven years to complete the project.

Atomic Energy of Canada Ltd (AECL) has reported that its Advanced CANDU Reactor (ACR) 1000 reactors of 1080 to 1150 MWe will have the flexibility to use a variety of fuels, including natural uranium, low enriched uranium, thorium and DUPIC (Direct Use of Spent Pressurised Water Reactor (PWR) Fuel). AECL noted that it is moving towards certification of ACR 1000 in Canada and the earliest in-service date for an ACR 1000 (Generation III+ 1200 MWe) unit is 2016. However, it is anticipated that use of thorium fuel will be in a later stage. In the shorter term, some jurisdictions are assessing the use of thorium cycles in existing CANDU 6 (700 MWe class) reactors.

A research program at Moscow's Kurchatov Institute involved the United States company, **Thorium Power Ltd**, and supported by funding from the United States Government is working to develop thorium-uranium fuel for the existing Russian Vodo-Vodyanoi Energetichesky (VVER-1000) reactors. While normal fuel uses enriched uranium oxide (UO_2), the modified design has a demountable centre portion and blanket arrangement, with plutonium fuel in the centre surrounded by a blanket of thorium uranium fuel. The Th^{232} becomes U^{233}, which is fissile, as is the core Pu^{239}. Blanket material remains in the reactor for nine years, but the centre portion is burned for only three years (as in a normal VVER) (World Nuclear Association Information Paper – Thorium, February 2009).

One of the main objectives of this program was to eliminate weapons grade plutonium by using it as thorium-plutonium fuel in nuclear reactors. More recently (Platts Nuclear Fuel 19 November 2007), Thorium Power stated that it was shifting the emphasis of its thorium fuel development to commercial deployment of thorium-based fuel in the United States.

Thorium Power reported at its annual shareholders meeting on 29 June 2009 that:

- By the end of 2008 the company had completed two phases of a five-phase VVER-1000 thorium fuel development process involving development and validation of preliminary thorium fuel design and fabrication process
- The remaining three phases include detailed design and irradiation of fuel samples in a test reactor followed by licensing the fuel technology to a commercial fuel fabricator for use of the developed thorium fuel in commercial VVER-1000 nuclear plants by 2021.

In parallel with the VVER-1000 program, Thorium Power also reported a 5 phase program for use of thorium fuel in pressurised light water reactors (PWR) outlining:

- Conceptual and preliminary thorium fuel design phases leading to irradiation of fuel samples in a test reactor by the end of 2010
- Detailed design, full scale testing and validation of fuel design followed by licensing to a commercial fuel fabricator for eventual use of the developed thorium fuel in commercial PWRs by 2018.

The thorium fuel design program for the VVER-1000 reactors is aimed primarily at the Indian market which has 2 VVER-1000s under construction, with 4 more planned and another 4 proposed. The thorium fuel design for the PWRs is aimed at 'western-style' reactors of which there are 191 in operation, another 22 under construction and 196 being proposed.

On 24 July 2009 it was reported in World Nuclear News (http://www.world-nuclear-news.org/newsarticle.aspx?id=25688 accessed on 26 July 2009) that the French public multinational industrial conglomerate, Areva, and Thorium Power signed an initial collaborative agreement on 23 July to investigate the potential use of thorium in Areva's light water reactors. Under the agreement Thorium Power will begin studies relating to the use of thorium in Areva's Evolutionary Power Reactor (EPR).

Resources

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

Most of the known thorium resources in Australia are in the rare earth-thorium phosphate mineral monazite within heavy mineral sand deposits, which are mined for their ilmenite, rutile, leucoxene and zircon content. Prior to 1996, monazite was being produced from heavy mineral sand operations and exported for extraction of rare earths. However, in current heavy mineral sand operations, the monazite is generally dispersed back through the original host sand (to avoid the concentration of radioactivity) when returning the mine site to an agreed land use. In doing so, the rare earths and thorium present in the monazite are negated as a resource because it would not be economic to recover the dispersed monazite for its rare earth and thorium content. The monazite content of heavy mineral resources is seldom recorded by mining companies in published reports.

Most of the known resources of monazite are in Victoria and Western Australia. Heavy mineral sands are being mined in the Murray basin deposits at Ginkgo in New South Wales, at Douglas in Victoria, and at Mindarie in South Australia.

Using available data, Geoscience Australia estimates Australia's monazite resources in the heavy mineral deposits to be around 6.2 Mt. The data on monazite and the thorium content in the monazite in the mineral sand resources is very variable, but the available sources include:

- Analyses for monazite and thorium in published and unpublished reports;
- published and unpublished analyses of thorium content in exported monazite concentrates; and
- monazite and thorium analyses on heavy mineral sand deposits in company reports on open file available at some State Geological Surveys.

Information from these sources was applied to resource data on individual heavy mineral sand deposits to estimate the thorium resources in these deposits. Where local data on the monazite

and thorium was not available, regional data were applied to individual deposits to estimate their monazite and thorium resources. Using this information, Australia's inferred thorium resources in the mineral sands were estimated to be around 376 600 tonnes.

Apart from heavy mineral sand deposits, thorium can be present in other geological settings such as alkaline intrusions and complexes, including carbonatites, and in veins and dykes. A significant example is the Nolans Bore rare earth, phosphate uranium deposit in Northern Territory, which is in fluorapatite veins and dykes This deposit contains about 81 810 tonnes of Th in 30.3 Mt of measured, indicated and inferred resources grading 2.8% rare earth oxides, 12.9% P_2O_5, 0.02% U_3O_8 and 0.27% Th.

In New South Wales, the Toongi alkaline trachyte plug is located 30 km south of Dubbo and hosts a measured resource of 35.7 Mt and 37.5 Mt of inferred resources grading 1.96% ZrO_2, 0.04% HfO_2, 0.46% Nb_2O_5, 0.03% Ta_2O_5, 0.14% Y_2O_3, 0.745% total REO, 0.014% U_3O_8, and 0.0478% Th, giving a total of about 35 000 tonnes contained Th. This deposit is owned by **Alkane Resources Ltd** and is referred to as the Dubbo Zirconia project.

A Demonstration Pilot Plant (DPP) was constructed and commissioned in May 2008 at the **Australian Nuclear Science and Technology Organisation** (ANSTO), Lucas Heights. The DPP is designed to test the flowsheet and provide the various products for distribution to potential end users. Alkane reported that two trial runs of the DPP were completed in 2008 and one more in the first quarter of 2009. The plant operated efficiently during this period with no significant issues and in the latter half of the run produced high quality zirconium and niobium products.

Other alkaline complexes with known rare earth and thorium mineralisation include Brockman in Western Australia. It is a large low-grade Zr-Nb-REE deposit hosted in altered trachytic tuff of Palaeoproterozoic age containing mineralised material of 50 Mt at 4400ppm Nb, 270ppm Ta, 1.04% Zr, 1240ppm Y, 350ppm Hf, 110ppm Ga and 900ppm REE (**Aztec Resources Ltd**, 2004 Annual Report). Historic company reports on open file on the Geological Survey of Western Australia WAMEX database show analyses for thorium in six separate drill hole intersections (in tuffs) of 16m to 28m averaging from 259 to 371ppm Th (Western Australia Geological Survey WAMEX database report A 40991).

Data on the thorium content of carbonatite intrusions in Australia is sparse. Mount Weld and Cummins Range in Western Australia have the most significant rare earth resources reported for carbonatites in Australia to date, with both having some thorium content.

The Mount Weld deposit in Western Australia occurs within a lateritic profile developed over an alkaline carbonatite complex with a reported measured, indicated and inferred REO resource of 12.24 Mt at 9.7% REO. The ThO_2 content of the deposit is estimated to be 712ppm which equates to 626ppm Th (personal communication B Shand, **Lynas Corporation Ltd** (Lynas) 17 June 2009).

Lynas also announced additional REO resources in the Southern Zone of 2.78 Mt of measured, indicated and inferred resources at 4% REO with an estimated ThO_2 content of 441ppm (388ppm Th) while in another part of the carbonatite complex there are 37.7 Mt of mostly inferred resources which include total lanthanides at 1.16% and 0.09% Y_2O_3 and a ThO_2 content of 479ppm (421ppm Th).

The company completed the first stage of mining activities on the Central Zone, and commenced the construction of a concentration plant at Mt Weld and an advanced materials plant in Malaysia. Both of these activities were suspended in the first quarter of 2009 because of uncertainty about financing arrangements for the project.

In March 2008, **Navigator Resources Ltd** reported inferred resources for Cummins Range in Western Australia carbonatite deposit of 3.55 Mt at 2% REO, 11.2% P_2O_5, 216ppm U_3O_8 and 36ppm Th. In other parts of the deposit however, sample analyses recorded in open file report A16613 in the Geological Survey of Western Australia WAMEX database averaged about 500ppm Th in the top 48m of weathered zone in one drill hole. Thorium-rich zones of 200 to 400ppm Th were intersected in two drill holes in fresh carbonatite and carbonated magnetite amphibolite to depths of 400m.

The Yangibana ferrocarbonatite-magnetite-rare earth-bearing dykes in Western Australia (termed 'ironstones') crop out over an area of 500 km² and form part of the Gifford Creek Complex. The dykes are part of a carbonatitic episode which intrudes the Proterozoic Bangemall Group. The ferrocarbonatite-magnetite-rare earth-bearing dykes occur as lenses and pods and are typically the last stage of carbonatite fractionation and are enriched in REEs, fluorite and U-Th mineralisation. The Yangibana prospect has a recorded resource of 3.5 Mt at 1.7% REO. The rare earths are in coarse grained monazite containing up to 20% Nd_2O_5 and 1600ppm Eu_2O_3. Whole rock chemical analyses of 21 ironstone samples collected from five prospects in the Yangibana area recorded more than 1000ppm Th for 10 of the samples (1062ppm to 5230ppm Th).

Australia's total indicated and inferred in-situ resources amount to about 543 700 tonnes Th. As there is no publicly available data on mining and processing losses for extraction of thorium from these resources, the recoverable resource of thorium is not known. However, assuming an arbitrary figure of 10% for mining and processing losses in the extraction of thorium, then the recoverable resources of Australia's thorium resources could amount to about 489 000 tonnes of Th.

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

Exploration

There has been no widespread exploration for thorium in Australia. However thorium is a significant component of some deposits being explored for other commodities. Thorium is present in the Nolans Bore deposit and in the Toongi intrusives complex. Heavy mineral concentrations within the King Leopold Sandstone and the Warton Sandstone, which constitute the Durack Range uranium project, also contain up to 2% Th in the heavy mineral concentrate **(Northern Mining Ltd** – announcement to the Australian Securities Exchange, 21 March 2007). **Western Desert Resources Ltd** reported that thorium was one of the commodities being explored for at Blueys and Cloughs Dam prospects near Alice Springs in Northern Territory with 599 to 1400ppm Th being reported in rock chip samples from the Blueys rare earth, zirconium, thorium prospect.

Production

There is no production of thorium in Australia, but it is present in monazite currently being mined with other minerals in heavy mineral beach sand deposits.

During the 1970's and 1980's Australia was producing REE minerals as a by-product of heavy mineral sand mining (12 000 tonnes of monazite and 50 tonnes of xenotime per annum).

Between 1980 and 1995 estimated production amounted to about 165 000 tonnes of monazite with about 160 000 tonnes sourced from heavy mineral sand mining in Western Australia. Most of the monazite was exported to France for extraction of rare earth elements, but the monazite plant in France was closed because its operators were unable to obtain a permit for the toxic and radioactive disposal site.

In current heavy mineral sand operations, the monazite fraction is returned to mine site and dispersed to reduce radiation as stipulated in mining conditions.

World Ranking

OECD/NEA & IAEA (2008)* has compiled estimates of thorium resources on a country-by-country basis. The OECD/NEA report notes that the estimates are subjective as a result of the variability in the quality of the data, a lot of which is old and incomplete. Table 3 has been derived by Geoscience Australia from information presented in the OECD/NEA analysis. The total identified resources refer to RAR plus inferred resources recoverable at less that US$80/kg Th.

Table 3. Estimated thorium resources by country

Country	Total Identified Thorium Resources (Reasonably Assured + Inferred Resources)* <USD 80/kg Th	
	('000 t Th)	%
Australia	489	18.7
United States	400	15.3
Turkey	344	13.2
India	319	12.2
Brazil	302	11.6
Venezuela	300	11.5
Norway	132	5.1
Egypt	100	3.8
Russian Federation	75	2.9
Greenland	54	2.1
Canada	44	1.7
South Africa	18	0.7
Others	33	1.3
TOTAL	**2610**	**100.1**

Sources: Data for Australia compiled by Geoscience Australia; estimates for all other countries are from: OECD/NEA & IAEA, 2008: Resources, Production and Demand. OECD Nuclear Energy Agency & International Atomic Energy Agency.
**See Uranium chapter for definitions of resource categories*

OECD/NEA & IAEA 2008 have grouped thorium resources according to four main types of deposits as shown in Table 3. Thorium resources worldwide appear to be moderately concentrated in the carbonatite type deposits accounting for about 30% of the world total.

Table 4. World and Australia's thorium resources according to deposit type (modified after OECD/NEA & IAEA (2008)) with Australia's thorium resources expressed as recoverable resources after an overall reduction of 10% for mining and milling losses.

	World deposits		Australian deposits	
Major deposit type	**Resources** (1000 t Th)	**Percentage**	**Resources** (1000 t Th)	**Percentage**
Carbonatite	1900	31.3	24	4.9
Placer deposits	1524	24.6	339	69.3
Vein-type deposits	1353	21.4	73	14.9
Alikaline rocks	1155	18.4	53	10.8
Other	258	4.2	No data	-
TOTAL	**6190**	**100.1**	**489**	**99.9**

The remaining thorium resources are more evenly spread across the other three deposit types in decreasing order of abundance in the placers, vein type deposits and alkaline rocks. In Australia, a larger proportion of resources is located in placers where the heavy mineral sand deposits account for about 70% of the known thorium resources in Australia.

Tin

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Tin (Sn) is used in solders for joining metals and pipes, as a coating for steel cans and in metal alloys. The largest single application for tin is in solders, which accounts for about half of current total world consumption. Solders are used in light engineering applications such as plumbing and sheet metal work, in the motor vehicle industry and in cans for various uses. Another major application for tin is coating steel sheet in the manufacture of tinplate, which accounts for about 16% of world tin consumption. Tinplate is used for containers in the form of tin cans for food products, drinks, oils, paints, disinfectants and chemicals.

Resources

Australia's Economic Demonstrated Resources (EDR) decreased by 40% to 145 kilotonnes (kt) Sn at December 2008, down from 247 kt Sn in 2007. This was due to a large decrease in tin resources at Greenbushes mine, Western Australia (WA) (refer 'Industry Developments').

Australia's EDR are in the deposits at Renison Bell and Mount Bischoff in western Tasmania (Tas), alluvial deposits in north east Tas, Mount Deans in Western Australia (WA) and Collingwood and Baal Gammon in north Queensland (Qld).

Accessible EDR

All of Australia's EDR for tin are unencumbered.

JORC Reserves

Joint Ore Reserve Committee (JORC) reserves comprise total tin in Proved and Probable Ore Reserves as defined in the JORC Code. In 2008, JORC Code reserves of 57 kt Sn accounted for approximately 39% of Accessible Economic Demonstrated Resources (AEDR).

Exploration

Tin exploration continued at several prospects in western Tas. After a hiatus of almost two decades, tin exploration resumed during 2007 and 2008 in the historic tin mining areas of far north Qld at the Herberton-Mount Garnet field, northern New England region of New South Wales (NSW) at the Inverell-Emmaville field and the Lachlan Fold Belt in the Bourke region of NSW. Data on tin exploration expenditures are not compiled by Australian Bureau of Agricultural and Resource Economics.

Venture Minerals intersected several zones of high grade tin tungsten (W) mineralisation at the **Mount Lindsay** prospect 15 kilometres (km) north west of Renison Bell tin mine and 20 km west of Rosebery in western Tas. The prospect is in magnetite (Fe_3O_4)-rich skarns within the contact aureole of the Meredith granite, which is part of a suite of Devonian granites that are the source rocks for a number of large tin, tungsten and magnetite deposits in western Tas and King Island in Bass Strait. The best intersection in the main zone was 12 metres (m) averaging 1.84% Sn and 0.26% WO_3. A second zone approximately 150m to the west was drilled and the best intersection recorded was 6m averaging 0.51% Sn and 0.58% WO_3. These zones contain approximately 33% Fe and the resources of magnetite, as well as tin, are being evaluated.

Malachite Resources continued exploration at a number of deposits in the Inverell district in northern NSW – mainly the **Sheep Station Hill** greisen deposit, **Newstead** alluvial Sn-W deposits and the **Standon** vein prospect. YDC Resources commenced exploration at the **Giants Den** alluvial deposits near Bendemeer, also in northern NSW

YDC Resources Ltd continued drilling at the **Doradilla** project 55 km south east of Bourke, NSW. The Doradilla-Midway-3KEL tin deposits are within a linear skarn unit which can be traced for more than 17 km along strike. The top 40-60m of the skarn are highly weathered. The resource is limited to the weathered zone (laterite) where tin is hosted in stanniferous goethite, garnets, secondary cassiterite

and minor primary cassiterite. YDC also continued exploration drilling at the **Tallebung** tin-tungsten deposit, 70 km north west of Condobolin in central NSW.

Outback Metals continued exploration drilling at the **Mount Wells** tin-copper deposit 200 km south east of Darwin in the Northern Territory (NT).

Production

Australia's mine production in 2008 was 1783 tonnes Sn in concentrates, which was 14% lower than in 2007. There was no production of refined tin in 2008 compared with 118 tonnes Sn of refined tin ingots in 2007 from smelting of concentrates at Greenbushes (WA). The decrease in Australia's mine production was due to the closure of Collingwood operations in mid-2008 and cessation of tin production at Greenbushes in 2007. Total exports for 2008 were 2784 tonnes Sn valued at $45 million.

World Ranking

Australia's EDR for tin was ranked at eighth in the world with the major resources of EDR in China, Indonesia, Peru, Brazil, Malaysia, Bolivia and Russia.

Industry Developments

Tin prices (London Metal Exchange) rose progressively from US$6000 a tonne in mid 2005 to a peak of more than US$25 000 in May 2008, and then fell progressively to end the year at US$10 000.

Metals X Limited, Australia's main tin mining company in 2008, re-commenced mining operations in western Tas at the historic **Mount Bischoff** open cut 80 km north of Renison in March and the **Renison Bell** underground mine near Zeehan in May. Ores from both mines were blended for feed to the Renison concentrator. In addition to the recovery of tin, a copper (Cu) circuit was established to recover copper as a co-product. Annual production is planned to be 8000-10 000 tonnes of tin in concentrates and 1000-1500 tonnes copper in concentrates.

Metals X Limited completed feasibility studies into the recovery of tin from tailings produced by historic processing of tin ores at Renison Bell mine. Resources in the tailings dam were estimated to be 18.2 Mt averaging 0.42% Sn and 0.2% Cu which represents 76 000 tonnes contained tin and 36 000 tonnes contained copper. The company reported that a combination of sulphide flotation and tin flotation techniques had produced a low grade concentrate which would be fumed to recover the tin.

In mid-2008, Metals X closed the **Collingwood** mine 30 km south west of Cooktown in north Queensland because it had not achieved planned grades and metal production. The company reported that mining had shown that the greisen tin zones were more erratic in shape and grade distribution than predicted by resource drilling.

In the Herberton-Mount Garnet field 110 km south west of Cairns, Consolidated Tin Mine Ltd (CTM) completed a drilling program at the **Gillian** (5 km south west of Mount Garnet), **Pinnacles** (6km north east of Mount Garnet) and **Deadman's Gully** (25 km north east of Mount Garnet) tin deposits. These deposits are in iron-rich skarns adjacent to granitic intrusions. In April 2009, the company reported revised resource estimates for these projects: Gillian 3 million tonnes (Mt) averaging 0.8% Sn, Pinnacles 1.9 Mt averaging 0.4% Sn and Deadmans Gully 0.4 Mt averaging 0.5% Sn. Although these deposits have been known since the 1970s, they have not been exploited because complex tin mineralogy makes it difficult to recover the tin. However, the company is investigating new metallurgical techniques for processing these ores.

Van Dieman Mines continued development of the **Scotia** and **Endurance** alluvial tin and sapphire deposits in north east Tas. A drilling program was completed into part of the Scotia deep lead to confirm the historic government drilling data. The company reported that results were broadly consistent with the earlier drilling and will be used to prepare JORC-compliant ore reserve and mineral resource estimates. Stripping and dewatering of an area of the Scotia palaeochannel was completed during the year. Mining of alluvials and production of tin concentrates from the plant are planned to commence in 2009.

In November 2008, Stonehenge Metals suspended operations of the gravity plant at the **Granville** tin project 20 km north of Zeehan in western Tas because of difficulties in processing wet clay-rich ores. The project has tin resources in the Granville East and Central Big 'H' deposits (both are strata-bound carbonate replacement type deposits), and the North Heemskirk deep lead alluvial deposit.

At **Greenbushes** mine, production of tin ceased in 2007 with the closure of the smelter, and production of tantalum concentrates ceased in December 2008 when the metallurgical plant was placed on care-and-maintenance. Talison Minerals reported revised estimates of mineral resource for tantalum and lithium however no resources for tin were reported. Tin resources for Greenbushes operations have not been publicly reported for more than a decade. Previous historical estimates of tin resources for Greenbushes were not included in Australia's EDR for 2008.

Tungsten

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Tungsten (W) metal and its alloys are amongst the hardest of all metals. It occurs as wolframite, (Fe, Mn)WO_4, and scheelite, $CaWO_4$. Tungsten carbide has a hardness approaching that of diamond and is used for cutting and wear-resistant materials primarily in the metalworking, mining, oil drilling and construction industries. Tungsten alloys are used also in electrodes, filaments (light bulbs), wires and components for electrical, heating, lighting, and welding applications.

Resources

Australia's total Economic Demonstrated Resources (EDR) at December 2008 was 111.5 kilotonnes (kt) W, an increase of 29% over the resources in 2007.

Accessible EDR

All of Australia's EDR for tungsten are unencumbered.

Exploration

Data on exploration expenditure for tungsten are not reported by Australian Bureau of Statistics. Tungsten prices have risen substantially since 2004. In response to these rises, companies have commenced exploration and re-evaluation of old abandoned tungsten mines and deposits, mainly in north Queensland, Tasmania and Northern Territory.

Drilling by Peel Exploration Limited at the **Attunga Prospect 1** scheelite deposit, near Tamworth, New South Wales intersected high grade tungsten-molybdenum zones including 2m at 24.21% WO_3 and 1.71% Mo from 22m, which was part of a larger interval of 42m at 2.09% WO_3 and 0.17% Mo. Mineralisation occurs in a northerly plunging pipe within skarn developed at the contact with a granitiod intrusion.

Production

During 2008, scheelite concentrates were produced at the Kara mine (Tasmania) and Wolfram Camp mine (north Queensland). Kara scheelite mine near Hampshire in northwest Tasmania produced 19 tonnes of scheelite concentrates averaging 55.7% WO_3, representing 8.4 tonnes contained W. Scheelite and magnetite were produced from skarns within Ordovician limestone adjacent to the contact with Devonian granite. A trial shipment of 5.5 tonnes of wolframite concentrate was exported by Queensland Ore Ltd from its Wolfram Camp mine near Cairns, before operation were suspended in late 2008 due to economic considerations.

World Ranking

China has the world's largest resources of tungsten with approximately 60% of world resources. Other nations with large resources include Canada and Russia.

World production of tungsten totalled 54.6 kt in 2008, and was dominated by China which accounted for 75% of production. Other large producers were Russia and Canada. In recent years the Chinese Government took steps to regulate production and control the release of Chinese tungsten on to the world market. The lack of supplies of tungsten concentrates from China, together with increased demand in China and elsewhere, has resulted in higher prices since 2005.

Industry Developments

In September 2008, Queensland Ores Ltd made the first shipment of tungsten concentrates to China from its **Wolfram Camp** tungsten-molybdenum mine, 90 km west of Cairns, in north Queensland. This is the first export of tungsten concentrate from Australia in more than 20 years. However, the company suspended mining operations due to the downturn in the world economy and weakness in molybdenum prices. The Wolfram Camp deposit has Measured Resources of 598 200 tonnes averaging 0.42% WO_3 and 0.17% MoS_2, Indicated Resources of 111 500 tonnes averaging 0.41% WO_3 and Inferred Resources of 238 300 tonnes averaging 0.4% WO_3 and 0.2% MoS_2.

As part of a feasibility study, Vital Metals Limited announced updated resources for its **Watershed** project, 25 km north east of the old Mount Carbine mine in far north Queensland. At a cut-off grade of 0.15% WO_3 , Measured Resources were 1.8 million tonnes (Mt) averaging 0.29% WO_3, Indicated Resources 7.7 Mt averaging 0.28% WO_3 and Inferred Resources of 5.7 Mt averaging 0.3% WO_3.

In June 2008, Icon Resources Ltd reported Inferred Resources of 1.05 Mt with an estimated recovered grade of 0.1% WO_3 in the old **Mt Carbine** open pit which closed down in 1987, and an Inferred Resource of 9.6 Mt averaging 0.2% WO_3 beneath the open pit.

King Island Scheelite formed a joint venture with Chinese Hunan Nonferrous Metals Corporation to redevelop the **King Island** scheelite mine. It is proposed to mine and process 600 000 tonnes of ore per year to produce 3000 tonnes of tungsten oxide annually. Development costs were estimated to be $110 million. The global resources at a cut-off grade of 0.25% WO_3 down to 308m below sea level was reported as Indicated Resources 13.2 Mt averaging 0.64% WO_3 and Inferred Resources of 200 000 tonnes averaging 0.35% WO_3.

Venture Minerals has discovered two high grade tin-tungsten shoots within its **Mount Lindsay** project, 20 km west-northwest of Rosebery, Tasmania, associated with metamorphosed dolomites adjacent to the Meredith Granite. The deposit has Inferred Resources of 5.7 Mt averaging 0.3% WO_3 (based on cut-off grade of 0.10% WO_3) and Inferred Resources of 23 Mt averaging 0.2% Sn (based on cut-off grade of 0.1% Sn).

Thor Mining PLC reported total Proved and Probable reserves of 2.21 Mt grading 0.47% WO_3 and 0.21% MoS_2 for its **Molyhil** project in the Northern Territory. Proved ore comprise 0.461 Mt grading 0.47% WO_3 and 0.30% MoS_2 and Probable Reserves comprises 1.75 Mt grading 0.47% WO_3 and 0.19% MoS_2. The company proposes to develop an open cut operations.

Uranium

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Major uses for uranium are as fuel in nuclear power reactors for electricity generation, in the manufacture of radioisotopes for medical applications and in nuclear science research using neutron fluxes.

Electricity generation from nuclear power reactors is an internationally proven technology and, in many parts of the world, is competitive with fossil fuel electricity generation. At January 2009 there were 436 commercial nuclear power reactors operating in 30 countries, most of which are 'light water' type reactors. The total installed nuclear generating capacity was 372 000 MW (Megawatt). Nuclear reactors currently provide about 15% of the world's electricity - mainly base load electricity supply. A further 49 power reactors are under construction worldwide and a further 136 reactors are firmly planned (source: World Nuclear Association). The United States of America (USA) has the

largest number of reactors with 104, followed by France with 59, Japan 55 and the United Kingdom 19. Developing countries such as China and India are planning major expansions of nuclear power capacity and could become significant importers of uranium.

The nuclear power industry has been developing and improving reactor technology for more than five decades. Generation II reactors are typified by the nuclear reactors currently operating for electricity generation in the USA and some other countries. During the past 20 years many of these reactors have received extensions of operating licences from 40 to 60 years. In addition there has been increased operating efficiencies and improved maintenance which has resulted in increased electricity generation over the two decades, despite little increase in installed capacity.

The next generation of nuclear power reactors (referred to as Generation III and III+) are currently being built or planned for many countries. These reactors use advanced technology and the first facility of this type has been in use in Japan since 1996.

Generation IV reactors are being designed, however none have been built and they are unlikely to be operational before 2020[5]. In 2003 the Generation IV International Forum representing 10 countries selected six reactor technologies which will be the future of the nuclear power industry. Four of the six use fast neutron reactor technologies.

Natural uranium (mine production) contains about 0.7% U^{235} and 99.3% U^{238}. Commercial light water reactors use only U^{235} to generate electricity because it undergoes natural fission. Generation IV reactors will also 'burn' the U^{238} to produce plutonium which will then be used to generate electricity. Generation IV reactors can utilise uranium about 60 times more efficiently than current commercial nuclear reactors. Generation IV reactors will use a 'blanket' of U^{238} around the core, where much of the plutonium is produced. The blanket can be reprocessed to recover plutonium which is used as fuel in the reactor.

The technology and design of Generation IV reactors are aimed at:

- using passive safety features which require no active controls or operational intervention to avoid accidents in the event of malfunction,
- being more resistant to diversion of materials for weapons proliferation, and more secure from terrorist attack,
- using the uranium fuel efficiently by using U^{238} and plutonium, as well as all the U^{235}; and using spent fuel from current commercial reactors,
- greater fuel 'burn up',
- greatly reducing the amounts of high level waste compared with current reactors.

Current planning for high level radioactive waste (HLW) repositories in many countries considers the amount of waste from current commercial reactors used for electricity generation, i.e. the 'once through' fuel cycle. This will change when Generation IV reactors become commercially viable and advanced fuel processing is successful. Generation IV reactors will alter the nature and scale of HLW disposal by substantially reducing the volume of these wastes[6].

Uranium spot market prices fell from a peak of US$138 a pound (lb) for uranium oxide (U_3O_8) in July 2007 to US$53 per lb by the end of 2008.

Resources

Geoscience Australia prepares estimates of Australia's uranium (U) resources within categories defined by the Organisation for Economic Cooperation and Development's Nuclear Energy Agency and the International Atomic Energy Agency (the NEA/IAEA Scheme). The estimates in each category are for resources of recoverable uranium after losses due to mining and milling have been deducted (Tables 1 & 2).

5 World Nuclear Association, July 2009. Advanced Nuclear Power reactors. http://www.world-nuclear.org/info/inf08.html

6 Commonwealth of Australian Government, 2006: Uranium Mining, Processing and Nuclear Energy Review – Opportunities for Australia? Report to the Prime Minister by the Uranium Mining, Processing and Nuclear Energy Review Taskforce, December 2006.

Table 5. Australia's uranium resources at December 2008 (reported under corresponding categories of NEA/IAEA and Australian national schemes).

National Scheme	NEA/IAEA Scheme	Tonnes U recoverable (December 2008)
Economic Demonstrated Resources (EDR)	Reasonably Assured Resources (RAR) recoverable at less than US$80/ kg U	1 163 000
Paramarginal Demonstrated Resources	RAR recoverable at US$80–130/ kg U	13 000
Submarginal Demonstrated Resources	RAR recoverable at US$130–260/ kg U	3000
Economic Inferred Resources	Inferred Resources recoverable at less than US$80/ kg U	449 000
Paramarginal Inferred Resources	Inferred Resources recoverable at US$80–130/ kg U	48 000
Submarginal Inferred Resources	Inferred Resources recoverable at US$130–260/kg U	3000

Australia's EDR at December 2008 were estimated to be 1.163 million tonnes U, which represented an increase of 18% over the estimates for December 2007 (983 000 tonnes U). This was due mainly to a large increase in resource estimates for the Olympic Dam deposit in South Australia (SA). Resources also increased at Ranger deposit in the Northern Territory (NT) due to the initial resource estimates for Ranger 3 Deeps ore zone, and small increases in resources at Bigrlyi deposit (NT).

Australia had an additional 449 000 tonnes U in Inferred Resources recoverable at costs of less than US$80/kg U which are the world's largest resources in this category. These Inferred Resources are mainly in the south eastern part of the Olympic Dam deposit. There was a significant decrease in Australia's Inferred Resources during the year because much of these resources at Olympic Dam were transferred to Measured and Indicated categories.

Approximately 90% of Australia's total uranium resources in EDR are within the following six deposits:

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

Table 6. Uranium resources in States and the Northern Territory at December 2008.

	RAR recoverable at <US$80/ kg U	Inferred Resources recoverable at <US$80/kg U	Total Resources	Percentage of Australia's Total Resources
	Tonnes U	Tonnes U	Tonnes U	
South Australia	893 453	347 140	1 240 593	77%
Northern Territory	191 094	54 951	246 045	15%
Western Australia	59 607	28 525	88 132	6%
Queensland	19 132	18 815	37 947	2%
New South Wales	0	0	0	-
Victoria	0	0	0	-
Tasmania	0	0	0	-
Australia Total (rounded)	**1 163 000**	**449 000**	**1 613 000**	**100%**

Accessible EDR

Approximately 8% of uranium EDR is inaccessible for mining. During the year there was a marked increase in resources accessible to mining because the WA State Government lifted its ban on uranium mining and consequently all WA deposits are available for mining. All resources also are accessible in SA because State Government policies permit the development of new uranium mines. All uranium deposits in Queensland (Qld) remain inaccessible because the State Government's policy prohibits uranium mining. Applications for new mine developments in the Northern Territory are subject to approval by the Commonwealth Government Minister for Resources, Energy and Tourism. Inaccessible resources in the Northern Territory include the Jabiluka deposit, where the traditional Aboriginal land owners have not granted approval to mine the deposit, and the Koongarra deposit where Aboriginal land owner approvals and environmental issues are yet to be resolved.

JORC Reserves

JORC reserves comprise total uranium resources in Proven and Probable reserves as defined in the JORC Code. In 2008, JORC reserves of 264 150 tonnes U (recoverable) account for approximately 25% of accessible EDR.

World Ranking

Australia has the world's largest resources of uranium in RAR recoverable at <US$80/kg U (equates to EDR), with 38% of world resources in this category at December 2008. Other countries with large resources include Kazakhstan with 11%, Canada 11%, South Africa 7% and the Russian Federation 6%.

Olympic Dam is the world's largest uranium deposit. Based on ore reserves and mineral resources reported by BHP Billiton as at June 2008, Geoscience Australia estimated that the deposit contains approximately 30% of the world's total resources in RAR recoverable at <US$80/kg U.

Exploration

In 2008, uranium exploration expenditure increased to a record level of $220.5 million[7], which is 22% higher than the 2007 expenditure ($181.4 million). The majority of expenditure was in SA (42%), followed by the NT (26%), Qld (19%) and WA (13%). Uranium exploration expenditure in Australia has increased progressively since 2003, mainly because of the significant increases in spot market uranium prices, which reached a peak in July 2007 and subsequently declined during 2008.

BHP Billiton continued a major drilling program to explore for extensions of the **Olympic Dam** deposit to the south.

Exploration drilling continued at **Four Mile** deposit which is 8 kilometres (km) north west of the Beverley uranium mine in SA. Drilling intersected extensions of both Four Mile East and Four Mile West deposits. The main mineralised zone is in a sequence of sediments ranging from coarse sand/gravel to silt, is between 200 and 210 metres (m) below the surface and ranges from 1 to 8m thick.

In the Mount Isa region, Paladin Energy (and joint venture partners) continued drilling at **Valhalla, Skal, Andersons, Duke-Batman and Honey Pot** uranium-vanadium deposits. Drilling intersected mineralisation within hematite feldspar breccias and albitites at these deposits and revised estimates of resources were reported.

Energy Metals Australia Ltd completed an exploration drilling campaign at the **Mulga Rock** deposit in WA and reported total Inferred Resources for the deposit of 15 810 tonnes U_3O_8 (at cut off grade 0.05% U_3O_8).

Thundelarra Exploration Ltd intersected uranium mineralisation at **Thunderball** prospect, near Hayes Creek in the NT.

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7 ABS Mineral and Petroleum Exploration, December quarter 2008

Haddington Resources Ltd intersected significant zones of uranium mineralisation at the **Liberator** prospect in the Mount Schoobridge area, 60 km south-south-east of Rum Jungle (NT).

Uranium Equities intersected mineralisation in the **N147** prospect southeast of Nabarkek in Arnhem Land, NT.

Production

Production for 2008 from Australia's three uranium mines were Ranger 5342 tonnes U_3O_8, Olympic Dam 3943 tonnes U_3O_8, and Beverley in situ recovery operations 659 tonnes U_3O_8 for a total Australian production of 9944 tonnes U_3O_8 (8432 tonnes U), 2% less than for 2007. Australia, with 19.2% of world uranium production in 2008, is the world's third largest producer after Canada and Kazakhstan.

Exports

Exports in 2008 were 10 707 tonnes U_3O_8 (9080 tonnes U) valued at $737 million. Exports of Australian uranium are controlled by stringent safeguards conditions which ensure that it is used only for peaceful purposes and does not enhance, or contribute to, any military applications. These conditions are given effect through bilateral safeguards agreements between Australia and the importing country. In the case of non-nuclear-weapons countries, it is a minimum requirement that International Atomic Energy Agency (IAEA) safeguards apply to all existing and future nuclear activities in that country. In the case of countries with nuclear weapons, there must be a treaty-level assurance that Australian uranium will be used only for peaceful purposes and that it must be subject to that country's safeguards agreement with the IAEA.

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

Industry Developments

Olympic Dam (SA): The Environmental Impact Statement (EIS) for Olympic Dam Expansion was released for public comment in May 2009. This expansion is based on a large open pit to mine the south-eastern portion of the deposit. At full production, it is proposed that the open cut and underground operations will mine a total of 80 million tonnes per annum (Mtpa) of ore with annual production estimated to reach 750 000 tonnes refined copper, 19 000 tonnes U_3O_8, 800 000 ounces gold and 2.9 million ounces silver. Removal of overburden is scheduled to commence in 2010 and processing of ore from the open cut to commence in 2016. The capacity of the existing underground mine will be increased to approximately 20 Mtpa by 2015. It is planned that the smelting operation will produce 350 000 tonnes per annum (tpa) of refined copper. An additional 1.6 Mtpa of copper concentrates containing significant levels of uranium will be exported for further processing overseas.

BHP Billiton's estimates of ore reserves and mineral resources are shown in Table 7.

Table 7. Olympic Dam Mineral Resources and Ore Reserves at June 2008.

	Million tonnes	Copper %	U_3O_8 kg/t	Gold g/t	Silver g/t
Total resources* Measured + Indicated+ Inferred	8339	0.88	0.28	0.31	1.50
Total reserves	473	1.86	0.60	0.76	3.95

** Mineral Resources includes Ore Reserves*
Source: BHP Billiton Annual report 2008

Monitoring groundwater quality at Beverley in situ recovery uranium mine, South Australia (Heathgate Resources Ltd)

Ranger mine (NT): Construction of a plant to treat stockpiled lateritic ores was completed in 2008 which will increase production of U_3O_8 by 400 tpa.

A new radiometric ore sorting plant was commissioned and will upgrade 350 000 tpa of low grade ore. Total production from all existing low grade stockpiled ores is expected to be 1100 tonnes U_3O_8.

ERA Ltd proposes to construct a heap leach facility for the extraction of up to 20 000 tonnes U_3O_8 contained in low grade mineralisation, both in situ and in stockpiles.

Exploration drilling in the Ranger 3 Deeps area during 2007 and 2008 has defined a zone of high grade mineralisation over a strike length of 1.2 km immediately east of the operating pit. Construction of an underground decline to enable underground exploration is proposed to commence in 2010. The company considers it likely that the mineralisation would be mined by an underground mine.

Total reserves plus mineral resources for Ranger showed a marked increase from 100 240 tonnes U_3O_8 at December 2007 to 159 300 tonnes U_3O_8 at December 2008 mainly as a result of the initial resource estimates for Ranger 3 Deeps.

ERA Ltd reported that the first shipments of uranium to China were made during the year.

Beverley (SA): Heathgate Resources operates the Beverley in situ recovery (ISR) mine located on the arid plains between the North Flinders Ranges and Lake Frome, approximately 300 km north east of Port Augusta, SA. During recent years, exploration has identified new zones of uranium mineralisation extending to the east of the Beverley mining lease and additional mineralisation in an area to the south. In August 2008, the Minister for the Environment, Water, Heritage and the Arts approved the expansion of the Beverley mineral lease following the outcomes of an environmental impact assessment under the *Environment Protection and Biodiversity Conservation Act*. Mining commenced in these areas in early 2009.

Four Mile (SA): ISR mining will be used at the Four Mile deposit. An ion exchange plant will be built at Four Mile and the resin will be trucked to the Beverley plant for recovery of uranium. The environmental impacts of the project were assessed under the *Environment Protection and Biodiversity Conservation Act* and a Public Environment Report was released in January 2009.

Geoscience Australia provided technical advice to Department of Environment, Water, Heritage and Arts as part of the assessment process. The Commonwealth Environment Minister approved the project in July 2009. Production is scheduled to commence at Four Mile East deposit in 2010.

Honeymoon uranium project (SA): Construction of an ISR mine and processing plant commenced during 2008 and production is planned to commence in 2010 at 400 tpa of U_3O_8. The Japanese trading company Mitsui purchased a 45% share of the project from Uranium One Australia Pty Ltd in October.

Oban project (SA): During 2008, exploration drilling outlined a new zone of uranium mineralisation to the west of Oban deposit 65 km north of Honeymoon mine which extended over an area of more than 60 000 square metres within sands of the Eyre Formation. In early 2009, Curnamona Energy received South Australian Government approval for a field leach trial and construction of the plant commenced.

Yeelirrie project (WA): BHP Billiton is undertaking drilling at Yeelirrie to upgrade the resource estimate and has commenced a feasibility study for development of the deposit. Yeelirrie currently has total resources of 52 500 tonnes U_3O_8 with an average grade of 0.15% U_3O_8. The company applied to the Australian Government to commence an EIS process for the proposed mine development.

Crocker Well deposit (SA): PepinNini Minerals and Sinosteel joint venture have commenced an environmental impact assessment process to obtain government approval for development of the Crocker Well deposit.

MegaUranium submitted an application to WA State government to develop **Lake Maitland** project WA.

Other developments

The new Liberal-National government in WA lifted the ban on uranium mining in the state after its election in September 2008.

New legislation to establish a uranium royalty regime in the NT was introduced in the Australian Parliament in December 2008 and is expected to come into effect in the second half of 2009.

Geoscience Australia is preparing a *National In Situ Recovery Uranium Mining Best Practice Guide*, under a Steering Group chaired by Commonwealth Department of Resources Energy and Tourism, to assist the Government to meet its commitments on best practice uranium mining.

Vanadium

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

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

Vanadium is sold as vanadium pentoxide (V_2O_5), or less commonly as vanadium trioxide (V_2O_3) and as an alloy of iron and vanadium, most commonly as FeV80 which has 80% contained vanadium, or as FeV50. V_2O_5 is typically quoted in US$ per pound (lb), while FeV is quoted in US$ per kilogram (kg).

Primary production of vanadium from mining and processing of magnetite ores accounts for only 29% of annual world production of vanadium. The majority of world production of vanadium (56%) is recovered from slag produced as a by-product of steel making, while the remaining world production (15%) is recovered from wastes including fly ash and oil residues.

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

Resources

Australia's Economic Demonstrated Resources (EDR) of vanadium increased by 95% in 2008 to 1750 kilotonnes (kt) from 898 kt in 2007. Growth in EDR was recorded at Balla Balla mid-way between Karratha and Port Hedland in Western Australia (WA), Barambie 80 kilometres (km) north of Sandstone, WA, and Bigrlyi located 390 km north west of Alice Springs, in the Northern Territory (NT).

Historically, Australia's EDR have fluctuated because of the economic impacts of volatile prices and the nature of the vanadium market, which is supplied largely from secondary sources that rapidly increase or decrease output in response to price trends.

Accessible EDR

All of Australia's EDR for vanadium are unencumbered.

World Ranking

China, the Russian Federation and South Africa have the world's largest resources of vanadium. Australia has the world's fourth largest resources.

Exploration

Data on exploration expenditure for vanadium are not available. Exploration continued at the Balla Balla, Barrambie and Gabanintha deposits (WA), and at the Bigrlyi deposit (NT).

Production

There was no production of vanadium in Australia during 2008 and only a limited period of mining at Windimurra (WA). While there are a number of vanadium deposits in Australia, Windimurra has been the only deposit mined in recent years. Most of the world's mine production of vanadium during the year was from South Africa (38%), China (33%) and Russia (27%).

Industry Developments

In late 2008, mining re-commenced at Windimurra deposit (WA) with run-of-mine stockpiles being built. It was proposed that the mine would produce 6400 tonnes per annum (tpa) of ferrovanadium and 1000 tpa of vanadium pentoxide, which would represent about 8% of the world market. In February 2009, administrators were appointed after the company's operations were suspended.

Windimurra Vanadium Limited: announced an increase in total resources for Windimurra deposit to 176.59 million tonnes (Mt) grading at 0.46% V_2O_5. Included in this total resource are proven ore reserves of 40.7 Mt grading at 0.47% V_2O_5 and probable ore reserves of 57.1 Mt grading at 0.47% V_2O_5. Vanadium mineralisation occurs within a shallow-dipping magnetite-rich horizon on the eastern side of a large gabbroic intrusion.

Aurox Resources Limited: has secured environmental approvals from the Western Australian Government for the Balla Balla vanadium-titanium-iron ore project. A new feasibility study on capital cost estimates for the project confirmed the initial estimates for the plant, slurry pipeline and port infrastructure at just over $1 billion, with operating cost calculated at $36 a tonne of concentrate mined, processed, delivered to Port Hedland via slurry pipeline and despatched for export by ship loader. The slurry pipeline study will look at a facility approximately 110 km long with capacity to transport 10 million tonnes per annum (Mtpa). It also is carrying out titanium test work in China to determine the viability of producing a saleable ilmenite product from the project. Mining is expected to commence in early 2012. Recent resource estimates for the project were reported as Proven Reserves being 180.4 Mt grading at 0.63% V_2O_5, 14.0% TiO_2, and 45.2% Fe, and Probable Reserves being 26.9 Mt grading at 0.62% V_2O_5, 13.5% TiO_2, and 45.36% Fe. Balla Balla is a titaniferous magnetite segregated zone within a large mafic/ultramafic intrusion

In February 2009, as part of the feasibility study of its Barrambie Project, **Reed Resources Ltd** reported total Indicated plus Inferred Resources of 65.2 Mt grading at 0.82% V_2O_5, 17.3% TiO_2 and 49.2% Fe_2O_3.

Yellow Rock Resources Limited: released an updated resource estimate in January 2009 on its Gabanintha vanadium-iron-titanium project, 43 km south east of Meekatharra, WA. Based on a cut-off grade of 0.35% V_2O_5, the project comprises a measured resource of 94.9 Mt grading at 0.56% V_2O_5, 27% Fe, and 7.2% TiO_2, an Indicated Resource of 34.68 Mt grading at 0.69% V_2O_5, 31.9% Fe, and 8.5% TiO_2, and an Inferred Resource of 21.9 Mt grading at 0.74% V_2O_5, 33.9% Fe, and 9.0% TiO_2. The Gabanintha deposit contains a Windimurra style hanging wall ore zone and a Balla Balla style foot wall zone.

Energy Metals Limited: upgraded the resource estimates for the Bigrlyi project, NT, as it commenced its pre-feasibility study of the project, including further metallurgical testwork. Based on a cut-off grade of 500 parts per million (ppm) U_3O_8, the deposit contains Indicated Resources of 2.3306 Mt grading at 1739 ppm U_3O_8 and 2429 ppm V_2O_5 and Inferred Resources of 5.231 Mt grading at 1250 ppm U_3O_8 and 2705 ppm V_2O_5.

Zinc, Lead, Silver

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Zinc (Zn) is the 23rd most abundant element in the earth's crust and the 4th most common metal in use after iron, aluminium and copper. The construction, transport and appliance manufacturing industries use large amounts of zinc, mainly as anti-corrosion coatings (galvanizing) on sheet steel, steel beams, vehicle panels, chain-link fencing, guard rails and light posts. World-wide, around four million tonnes (Mt) of zinc is used annually to protect around 100 Mt of steel, representing almost half of the world's total consumption of zinc. The widespread use of zinc as a protective coating is due mainly to its resistance to normal weathering. This is an electrochemical reaction known as galvanic action. Zinc is more reactive than iron or steel and thus will attract almost all local oxidation. A protective surface layer of oxide and carbonate forms as the zinc corrodes. Zinc is used also in brass (almost 20% of zinc use), alloys (16%) such as for die cast precision components, pigments, salts, as oxide additives to rubber and for agricultural chemicals as well as for wrought or rolled products. Zinc metal is produced in Australia at Sun Metals' Townsville refinery in Queensland (Qld) and at Nyrstar NV's Hobart refinery in Tasmania (Tas).

The widespread occurrence of **lead** (Pb), its relatively simple extraction and combination of desirable properties have made it useful to humans since at least 5000 BC. In deposits mined today, lead, in the form of galena (PbS), is usually associated with zinc, silver (Ag) and sometimes copper (Cu) and is extracted as a co-product of those metals. The largest use is in batteries for vehicles which accounts for 80% of modern lead usage. The remaining 20% of applications include underwater cable sheathing, solder, casting alloys, chemical compounds, ammunition, glassware and radiation protection. Uses for lead could increase in the future in large storage batteries used for load-levelling of electrical power and in electric vehicles. The growing popularity of electric bikes, particularly in China, has led to the e-bike now consuming more than 8% of world lead production. More than half of the lead currently used is from recycling, rather than mining. Lead recycling plants jointly owned by Nyrstar NV and the Sims Group are in Melbourne, Victoria and in Sydney, New South Wales (NSW). Nyrstar NV's Port Pirie smelter in South Australia (SA) is the world's largest primary lead smelting facility and a leading global silver producer.

The relative scarcity, attractive appearance and malleability of **silver** make it suitable for use in jewellery, ornaments and household silverware. Its extensive use in coins throughout history has declined over the past 50 years. In Australia, the 1966 fifty cent piece was the last coin in general use to contain silver (80% Ag, 20% Cu). Silver is mined and produced mainly as a co-product of lead, zinc, copper and, to a lesser extent, gold (Au). Currently, jewellery, photographic paper and film, followed by electronics and tableware, are the most important users of silver. Other applications

include coatings for mirrors, for biocide and bacteriostatic activity in plastic and textiles formulations and as an anti-bacterial agent in areas such as water treatment including, for example, as an ioniser with copper in domestic swimming pools.

Resources

Australia's total resources of zinc, lead and silver remained fairly stable in 2008. Total identified resources of zinc fell slightly from 86 Mt in 2007 to 84 Mt in 2008, lead was unchanged at 53 Mt along with silver which remained at 110 kilotonnes (kt).

Zinc

Australia's Economic Demonstrated Resources (EDR) of zinc at 53 Mt is the world's largest holding, accounting for around 27% of world EDR. The 11 Mt increase in national EDR compared to 2007 is associated with the release of a new resource statement for the Dugald River deposit in Qld and a reassessment of resources at McArthur River in the Northern Territory (NT). Queensland continued to hold the largest resource with 32 Mt, or 60% of national EDR, predominantly at the Mount Isa, George Fisher, Century and Dugald River deposits. The NT again had the second largest EDR with 17 Mt, or 32% of national EDR, all at the McArthur River deposit. Following were NSW with 2 Mt EDR, mostly at the Broken Hill and Endeavor deposits, and Western Australia (WA) also with 2 Mt, mostly at the Golden Grove, Sulphur Springs, Jaguar and Pillara deposits. Paramarginal Demonstrated Resources of zinc fell to 7 Mt as a result of resource upgrades for Dugald River and McArthur River. Total inferred zinc resources decreased from 23 Mt in 2007 to 22 Mt in 2008.

Lead

Australia's EDR of lead increased by 4 Mt in 2008 to 27 Mt of contained lead and constituted 51% of Australia's total identified lead resources (53 Mt). Australia also contains the largest share of world EDR for lead at 33%. Queensland retained the top ranking with its EDR increasing from 16 Mt in 2007 to 17 Mt in 2008 which represents a 62% share of national EDR. In the NT, EDR increased from 5 Mt to 8 Mt or 32% of the national total as a result of a reassessment of resources at the McArthur River mine. New South Wales recorded a decrease in EDR from 1.6 Mt in 2007 to 1.4 Mt largely because of a decrease in reserves at Endeavor. Australia's Paramarginal Demonstrated Resources of lead decreased by 2 Mt to 7 Mt, which is 13% of total Identified Resources. Total inferred lead resources were largely unchanged in 2008 at 18 Mt.

Silver

EDR for silver is 61.4 kt which is 20% of world EDR. Queensland has 39 kt or 64% of Australian EDR, mainly in the Cannington, Mount Isa, George Fisher, Dugald River and Century deposits. Most other silver EDR occurs in SA (10 kt), the NT (7 kt), NSW (2 kt), WA (2 kt) and Tas (1 kt). In SA, almost all silver EDR is at Olympic Dam with some at Prominent Hill while in the NT silver EDR is largely at McArthur River and partly Browns, in NSW it is mostly at Broken Hill and Endeavor, and in WA, predominantly at Golden Grove, Spinifex Ridge and Jaguar.

Accessible EDR

All zinc, lead and silver EDR is accessible.

JORC Reserves

Of Australia's EDR of zinc, 42% occurs in the JORC Code ore reserves categories. The remaining EDR is made up of those Measured and Indicated resources as reported by mining companies and which Geoscience Australia considers will be economic over the long term. The zinc resource life using national EDR divided by annual production is 35 years, but using the ore reserve and dividing by annual production gives a resource life of only 15 years.

Of Australia's EDR of lead, 40% occurs in the JORC Code ore reserves categories. For lead, the national EDR/production ratio is 42 years, but if the ore reserve/production ratio is used it is 16 years.

For silver, JORC Code reserves account for around 43% of EDR and resource life is 32 years for EDR or 14 years for JORC reserves.

Exploration

In 2008, exploration spending on zinc-lead-silver was $133 million, 29% lower than in 2007. The 2008 expenditure was 18% of total base metal expenditure of $750 million compared to 27% in 2007. Expenditure on exploration for zinc-lead-silver made up 5% of all mineral exploration which, excluding petroleum, was $2.61 billion, and compared to 9% in 2007. Western Australia, Qld, SA and NSW were the focus of most of this exploration expenditure with WA accounting for $40 million or 30% of all zinc-lead-silver exploration.

Production

The 2008 Australian mine production of zinc, lead and silver was 1.52 Mt, 0.65 Mt and 1.93 kt respectively. Compared to 2007, production in 2008 was relatively stable, increasing only slightly for zinc and lead and increasing by 46 tonnes, or 2%, for silver. The majority of production was from Qld which contributed 918 kt, or 60% to national zinc production for 2008 (up 39 kt on 2007) along with 481 kt or 75% of lead (up 21 kt), and 1.6 kt or 82% of silver. Western Australia produced 200 kt of zinc and 25 kt of lead, while NSW produced 141 kt zinc and 71 kt lead, the NT 142 kt zinc and 37 kt lead and Tas 97 kt zinc and 33 kt lead. The Century zinc mine, which is located close to the Gulf of Carpentaria about 250 km north of Mount Isa in north west Qld, ranks in the top few globally in zinc production. Century produced 514 kt of zinc and 56 kt of lead as metal-in-concentrate in 2008. The Cannington mine, also located in north west Qld, is the world's largest and lowest cost single mine producer of both silver and lead and a significant producer of zinc. Cannington produced 251 kt of lead, 1.1 kt of silver and 61 kt of zinc in 2007–08. Also in Qld are Xstrata's Mount Isa mines which produced 283 kt of zinc, 167 kt of lead and 0.3 kt of silver in 2008.

The value of Australia's exports of zinc concentrates and refined zinc in 2008 totalled $2.3 billion, 45% less than the $4.2 billion in 2007 and 1% of the value of total merchandise exports. Although the tonnage of zinc exports increased by 2% to 1.5 Mt in 2008, the value of these exports was much lower than in 2007 because of lower zinc prices in 2008. The average price for zinc in 2008 was $2494 a tonne, 43% lower than the average of $4382 a tonne in 2007. The 2008 December quarter average price was 36% less than for the December quarter in 2007

Exports of lead totalled 604 kt in 2008, down 3% on 2007. The value of the 2008 exports was 16% lower at $1.7 billion compared to $2 billion in 2007. The difference was the result mostly of the average price for lead being 12% lower at $2886 a tonne compared to the average of $3283 a tonne in 2007. For silver, the average price was 9% higher at $559 a kilogram (kg) compared to the average of $513/kg in 2007. The value of Australia's mine production of silver was $1.1 billion in 2008 up 11% on 2007.

World Ranking

Based on United States Geological Survey data for other countries, Australia has the world's largest EDR of zinc (27%), lead (33%) and silver (20%). In terms of production, Australia ranks second for lead and zinc after China and fifth for silver after Peru, Mexico, China and Chile.

Industry Developments

Mount Isa and George Fisher (Qld): Xstrata Plc's George Fisher mine increased production in 2008 by 10% to 3.1 Mt of zinc-lead ore. The completion of the KG53 decline/incline project in September 2008 allowed for production from George Fisher North Upper Level to be trucked to the surface in the fourth quarter of 2008. The first ore was mined at Handlebar Hill open cut in June 2008 and produced 1 Mt of ore during the year. The Black Star open cut operation maintained ore production at 2.3 Mt. Throughput at the Mount Isa zinc-lead concentrator increased from 5 Mt in 2007 to 6.1 Mt in 2008 as the expansion project progressed. Cost savings were achieved through optimising reagent usage and improvements in energy efficiency. In 2008, zinc metal in concentrate rose by 25% to 283

kt. At the Mount Isa lead smelter, production was up by 33% to 167 kt of lead in bullion as a result of increased concentrate feed from the zinc-lead concentrator and increased volumes of third-party lead concentrate feed. Despite these many advances at the Mount Isa and George Fisher zinc-lead operations, an operating loss of US$54 million was reported as declining prices, lower mined grades and higher input costs outweighed the positive impact of higher mined production, increased ore throughput and improved recoveries.

Consequently, a strategic review aimed at optimising efficiency and productivity and securing the long-term future of Mount Isa operations during challenging operating conditions resulted in a restructure plan. This included placing Handlebar Hill on care and maintenance from early February 2009 while production from the large-scale Black Star open pit and the higher grade George Fisher operation will increase by 35% and 13% respectively. Together, and with stockpiled ore from Handlebar Hill, the operations will enable an optimised throughput at the expanded zinc-lead concentrator of 7.3 Mt, 20% higher than in 2008, with improved recoveries and increased operational efficiencies. Xstrata report this strategic operational change will result in a 23% increase in zinc metal output and a 17% increase in lead metal output over 2008 levels. Planned capital expenditure at Mount Isa will be reduced by 83% without impacting on the integrity of operations while further cost savings will be achieved through reducing and deferring the movement of waste material at Black Star by 40%. In total, operating costs at the Mount Isa zinc-lead operations are expected to be reduced by US$35 million or 32% in 2009.

McArthur River (NT): Xstrata reported the open pit development at McArthur River Mine was completed on schedule during 2008. Mining production increased marginally over 2007 levels to 2 Mt. The capacity of the concentrator was increased from 1.8 million tonnes per annum (Mtpa) of ore to 2.5 Mtpa, a design rate achieved in November 2008. Consequently, 2008 throughput increased by 12% to 2.1 Mt. Zinc metal in concentrate increased by 3% to 142 kt, as a result of increased throughput tonnage, but was partially offset by lower feed grade to the mill. Average head grades decreased from 10.2% in 2007 to 9.6% in 2008 in line with the mine plan. Production in December was reduced by approximately 25% in the light of market conditions and all mining and civil works were suspended on 17 December pending expansion re-approval. When stockpiled ore was exhausted on in January 2009, the operation was placed on care and maintenance. On 20 February 2009, the Federal Environment Minister approved the open pit development and operations have recommenced.

OZ Minerals Limited: In June 2008, Zinifex Limited, the owner of Century, Rosebery and Dugald River, merged with Oxiana Limited, owner of Golden Grove and Prominent Hill, to form OZ Minerals Limited as the world's second largest zinc producer. OZ Minerals faced financial issues soon after it was formed as a result of decreasing commodity prices and high levels of capital expenditure involved with the construction of the Prominent Hill operation and pre-strip mining at Century. In early 2009, a possible solution to OZ Minerals' refinancing issues came when China Minmetals Non Ferrous Metals Company Limited (Minmetals) agreed to buy OZ Minerals. Subsequently, Prominent Hill (located in the Woomera Prohibited Area) was excluded from the Minmetals purchase because the Australian Treasurer would not approve its sale on national security grounds.

Century (Qld): The Century mine is the world's second largest open pit zinc mine. In 2008, 514 kt of zinc in concentrate and 56 kt of lead in concentrate was produced at Century. This was slightly above the previous year's production. During 2008, a new ball mill was installed to enable increased zinc recovery from ore. OZ Minerals Limited reported mining costs were elevated in 2008, mainly because of the large volumes of pre-strip mining required. The Century deposit is covered by a large volume of overburden which requires removal to access the ore. Stripping costs peaked in recent years, but are declining progressively as waste stripping reduces over the remaining expected life of the Century ore body to 2015. Pre-strip mining volumes are expected to be 40% lower in 2009.

Golden Grove (WA): The Golden Grove operation consists of the Scuddles and Gossan Hill zinc and copper underground mines and the Scuddles plant. Total resources increased during 2008 by around 20% following delineation of resources at recent discoveries. Production was slightly increased for 2008 at 140 kt of zinc, 18 kt of copper, 47 755 ounces of gold, 3 million ounces (Moz)

Semi-autogenous grinding mills at metallurgical processing plant, Century zinc-lead mine, north Queensland (Minerals and Metals Group Ltd)

of silver and 13 kt of lead. All are contained metal in concentrate. In September 2008, OZ Minerals Limited announced it was planning to reduce zinc production at its Golden Grove mine by 35-40% and schedule higher copper production as a result of the weak zinc price. A few months later the company announced the Scuddles mine was to be put on care and maintenance in response to market conditions. Expansion studies at Golden Grove to investigate the addition of open pit copper mining and possible extensions of the underground mine were put on hold because of low commodity prices.

Rosebery (Tas): An exploration and delineation drilling program which commenced in 2006, Project Horizons, has resulted in a 65% increase in resources at Rosebery, potentially extending its mine life beyond 2020. In 2008, metal in concentrate produced was 85 kt of zinc, 29 kt of lead, 2 kt of copper and 30 675 ounces of gold. OZ Minerals Limited reported replacement of the grinding and flotation circuits at a cost of $125 million and an upgrade of the underground ventilation were both deferred in light of financing difficulties. However, work on a new tailings storage facility proceeded.

Broken Hill (NSW): A bid to merge the Broken Hill operations of CBH Resources Ltd and Perilya Ltd failed to proceed despite cost savings estimated at up to $200 million. Subsequently, Perilya Ltd entered into a financial arrangement in which Shenzhen Zhongjin Lingnan Nonfemet Co Ltd, China's third largest zinc producer, acquired 50.1% of Perilya. Perilya Ltd reviewed its Broken Hill operation in light of the significant fall in metal prices and implemented a plan to resize the operation from 1.8 to 0.95 Mtpa, which is expected to produce 55 kt of zinc and 50 kt of lead. Production was refocused on a lower tonnage, higher grade profile around mining remnant pillars and stopes with low development requirements in the Southern operation. At CBH Resources Rasp operation, the development decline was placed on care and maintenance from June 2008 with 2 400 metres (m) of development completed and at a depth of 350 vertical metres below the surface. At its current level the Rasp decline provides access to 70% of the first two years of planned production from three individual working levels within the Western Mineralisation (a previously unmined zinc lode) and from high grade lead lode remnants. Perilya also placed the North Mine and Potosi exploration decline on care and maintenance.

Endeavor (NSW): CBH Resources Limited reported that a revised mine plan was being adopted at Endeavor with lower mine production at higher grades to minimise cash outflows and remain viable during a period of lower metal prices. Workforce numbers were reduced from 384 to 233 in August 2008 and then to 115 in November 2008. Annualised ore throughput was reduced from 1 Mtpa to 800 kilotonnes per annum (ktpa) and then to 420 ktpa in November. Increasing the mine cut off grade at Endeavor resulted in a decrease in the size of the overall mining reserve. Paste backfill operations have been suspended while the mine produces at the 420 ktpa rate. Mine development has been cut back also, a move made possible by significant development carried out in the 2007-08 financial year. Production for 2008 at 47 kt zinc, 22 kt lead and 0.7 Moz silver was similar to 2007.

Angas (SA): Terramin Australia Ltd reported the 400 ktpa operation was commissioned in July 2008 at a cost of $71 million. Angas has a Probable Reserve of 2.4 Mt at 7% Zn, 2.7% Pb, 0.2% Cu, 31 grams per tonne (g/t) Ag and 0.5g/t Au. Over its seven year life, Angas is forecast to produce 320 kt of zinc concentrate (52% Zn) and 125 kt of lead concentrate (50% Pb, 4.5% Cu, 450g/t Ag and 7g/t Au). Zinc concentrates are trucked 70 km to Port Adelaide for shipment to Asia while lead-copper-gold-silver concentrates are trucked 200 km to the Nyrstar owned, Port Pirie smelter.

Mungana (Qld): A decline to access the Mungana underground base metal orebody was completed during 2008 with production commencing in September 2008. Construction of a new $80 million base metal concentrator and associated infrastructure commenced at Mungana in May 2008. At the proposed throughput of 350 ktpa at 12% Zn and 2% Cu, Mungana would produce 38 ktpa of zinc, 6 ktpa of copper, 5 ktpa of lead, 38 tonnes of silver and 7000 ounces of gold from a reserve of 1.35 Mt at 11.8% Zn, 2% Cu, 1.1% Pb, 124g/t Ag and 1g/t Au. A strategic review in October 2008 resulted in the prioritisation of higher margin orebodies at Mungana and Balcooma, increasing copper production and deferring the completion of the Mungana base metal plant as a result of the economic downturn. Ore from the Mungana operations is being trucked to the Mount Garnet polymetallic treatment plant. At Mount Garnet, the open pit was completed in June 2008. A portal for the development of the Mount Garnet underground orebody commenced in March 2008 and stoping commenced in February 2009 from an 800 kt reserve grading 7.5% Zn and 0.3% Cu.

RESOURCE LIFE

Copper smelting at Mount Isa, north Queensland (Xstrata plc)

Resource Life

To sustain the contribution of Australia's mineral resources to national economic performance in the medium and longer term, new good quality 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 are provided in the commodity review chapters, as an indicator of resource life. Ratios of Ore Reserves (as published by companies) to production are a much more conservative indicator of what is likely to be available for mining in the foreseeable future. It is important to note that these 'duration indicators' can change rapidly with significant changes in rates of production and/or major changes to resources.

Table 8 presents a comparison of the AEDR/production ratios as assessed over the past 11 years from 1997 to 2008. Over this period there has been a significant trend towards lower AEDR/production ratio for coal and iron ore, which are the net result of major increases in production and reassessment of resources.

Table 8: Years of accessible economic demonstrated resources (AEDR) at the production level for the year (rounded to nearest 5 years)

Commodity	1997	2002	2007	2008
Bauxite	70	85	85	85
Black coal	190	115	90	90
Brown coal	670	485	490	490
Copper	40	35	70	85
Diamond	5	5	10	10
Gold	15	20	25	30
Iron Ore	105	70	65	70
Lead	35	25	35	40
Manganese ore*	25	25	15	20
Mineral sands				
ilmenite	65	85	80	85
rutile	75	80	55	55
zircon	55	50	50	55
Nickel	55	105	140	130
Silver	35	20	25	30
Uranium	95	90	95	125
Zinc	35	20	30	35

**Resource life allows for losses which occur in beneficiating (upgrading) manganese ores.*

Commodities with resource life duration of less than 50 years are diamond (about 10 years at current rates of production), manganese ore (20), gold (30), zinc (35) and lead (40). Increases in the price of gold have contributed to increased expenditure on exploration for this commodity since 1980. There is a need for ongoing successful exploration in the short and medium terms to ensure sufficient available resources to maintain Australia's levels of exports of these commodities.

It is important to note that a long resource life for a particular commodity is not a guarantee that such resources will continue to be exploited in Australia. In an increasingly globalised and competitive commodity market, multinational mining companies are continually in search of mineral deposits offering most attractive returns on their investment. Such returns are influenced by the quality of the resources (grade and tonnage) as well as environmental, social and political factors, land access and even the location and scale of the existing mining operations owned by a multinational mining company.

The severe world financial crisis in 2008 has exacerbated these factors and has forced companies to reassess their options in regard both to existing and planned operations in Australia. In the case of black coal and iron ore, the initial impact of the world crisis caused some mining operations to scale back production, others delayed plans for expansion and some mines closed at the end of 2008. During 2009 however, recovery in mining operations and development plans were well under way for these commodities.

In the case of nickel, some multinational companies have recently closed sulphide and lateritic nickel mines in WA and Tasmania and have consolidated their operations at larger low cost mining operations – not necessarily in Australia. This is a consequence of the dominance of large multinational mining companies in the world mining industry.

By late 2008 almost all zinc-lead mines in Australia had scaled back, usually with a focus on higher grade ore and several operations moved to care and maintenance as a result of low zinc and lead prices. Lower copper prices, particularly in the last quarter of 2008, contributed to several of Australia's smaller copper mines moving to care and maintenance with three recently established low-grade copper mining companies being placed in administration.

For heavy mineral sands operations, there have been moves by some producers to divest themselves of low grade ilmenite deposits and concentrate on deposits that are more readily amenable to beneficiation or have a higher content of zircon.

Australia's continuing position as a premier mineral producer is dependent on continuing investment in exploration to locate good quality resources and to upgrade known deposits in order to compete on the world market, and investment in metallurgical beneficiation processes to improve metallurgical recoveries.

EXPLORATION

Exploration drilling at Weld Range iron deposit, Western Australia (Sinosteel Midwest Corporation Ltd)

Exploration

Mike Huleatt mike.huleatt@ga.gov.au

Overview

Australian mineral exploration spending in 2007–08 rose by 43.6% to a record $2461.5 million of which 41.1% was spent on the search for new deposits. Although Western Australia dominated with 51.2% of Australian mineral exploration spending, all States and the Northern Territory had record expenditure.

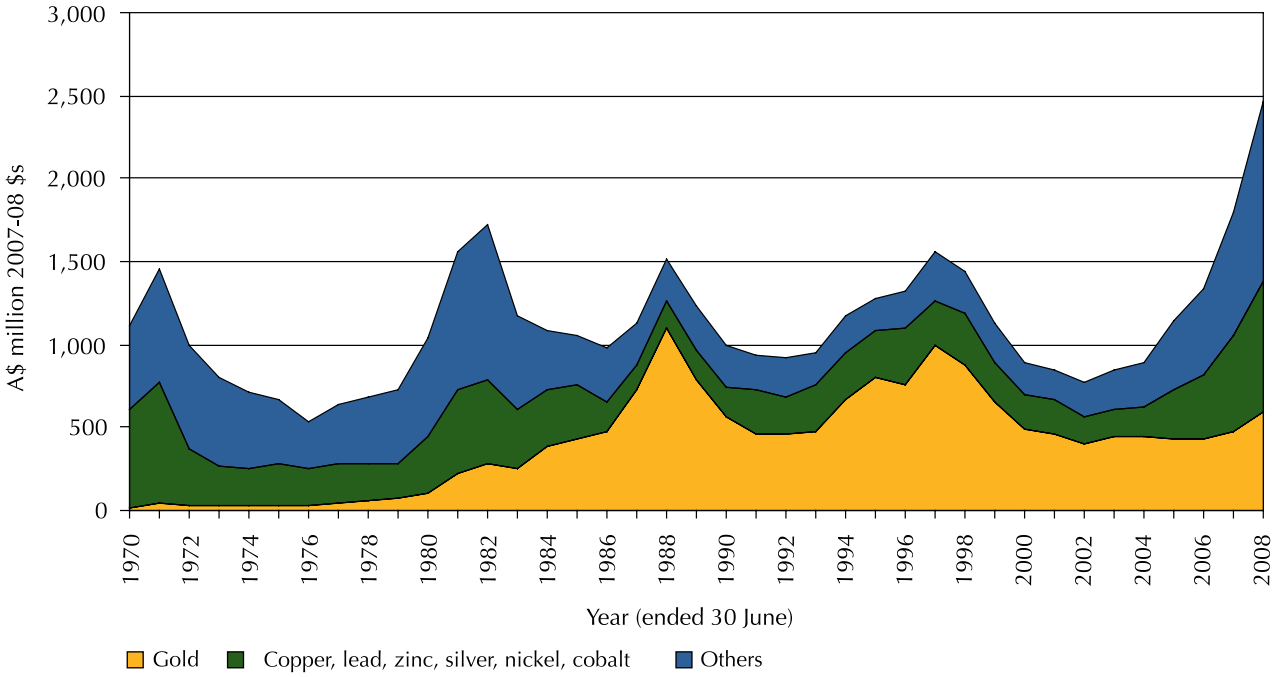
Gold remained the main single element target with a share of 24.1% of total spending but the base metals (copper, zinc-lead-silver, nickel-cobalt,) formed the largest single exploration target with 31.8% of total spending in 2007-08.

Review

Exploration resulted in significant increases in resources at known deposits and a substantial number of drill intersections of economic interest. The base metals group (copper, zinc-lead-silver, nickel-cobalt,) remained the main target ahead of gold and iron ore. Gold's share fell again to 24.1% of total spending**.** Strong growth was recorded in spending on all commodities except mineral sands which experienced a reduction of less than 15% and diamond which fell by just under 20%.

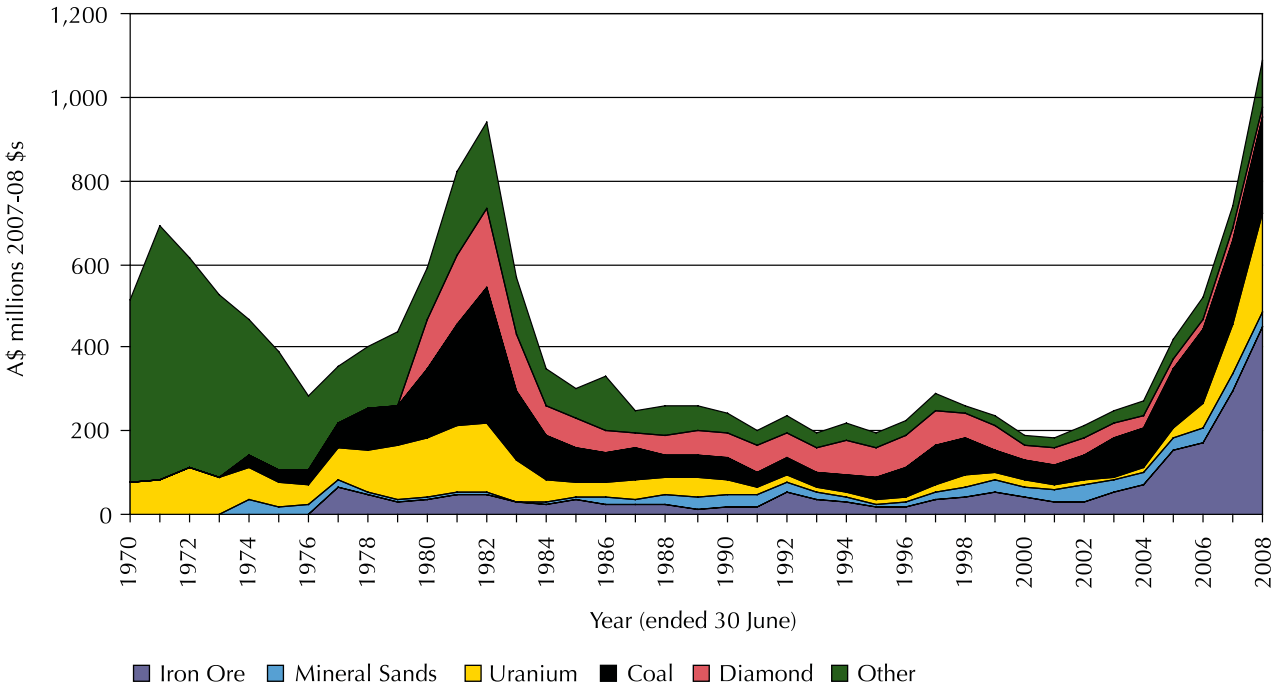
Australian mineral exploration expenditure rose by 43.6% to $2461.5 million in 2007–08 according to the Australian Bureau of Statistics (ABS). This was a record for annual current dollar expenditure for Australia. In 2007–08 constant dollars, expenditure was also a record after rising by 37.2% (Figs. 2 and 3).

Figure 2. Australian mineral exploration expenditures by commodity in constant 2007–08 dollars (Based on ABS data deflated by Consumer Price Index series).



The base metals group (copper, zinc-lead-silver, nickel-cobalt) remained the main exploration target in 2007-08 (Fig. 4). Base metal exploration spending rose by 41.2% to $783.4 million with expenditure on nickel exploration being the principal driver. Nickel exploration rose by 67.5% to $303.3 million and copper spending increased by 25.2% to $293.5 million. Exploration for lead-zinc-silver rose by 34.9% to $186.6 million. Gold exploration rose by 30.0% to $592.3 million which was 24.1% of total exploration compared to 26.6% in 2006-07 and 32% in 2005-06.

Figure 3. Australian mineral exploration expenditure, excluding gold and base metals, in constant 2007–08 dollars (Based on ABS data deflated by Consumer Price Index series).



Continued strong international demand and high prices for coal, iron ore and uranium resulted in significant growth in exploration spending for those commodities. Uranium exploration spending surged in 2007-08 rising by 103% to a record $231.6 million. This growth followed the listing of a large number of new companies with a uranium focus in the previous few years. Continuing strong international demand for iron ore resulted in exploration spending increasing by 57.7% to a record $449.8 million, the second largest expenditure for a commodity. Coal exploration spending continued to grow rising by 21.5% to a record $234.8 million.

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

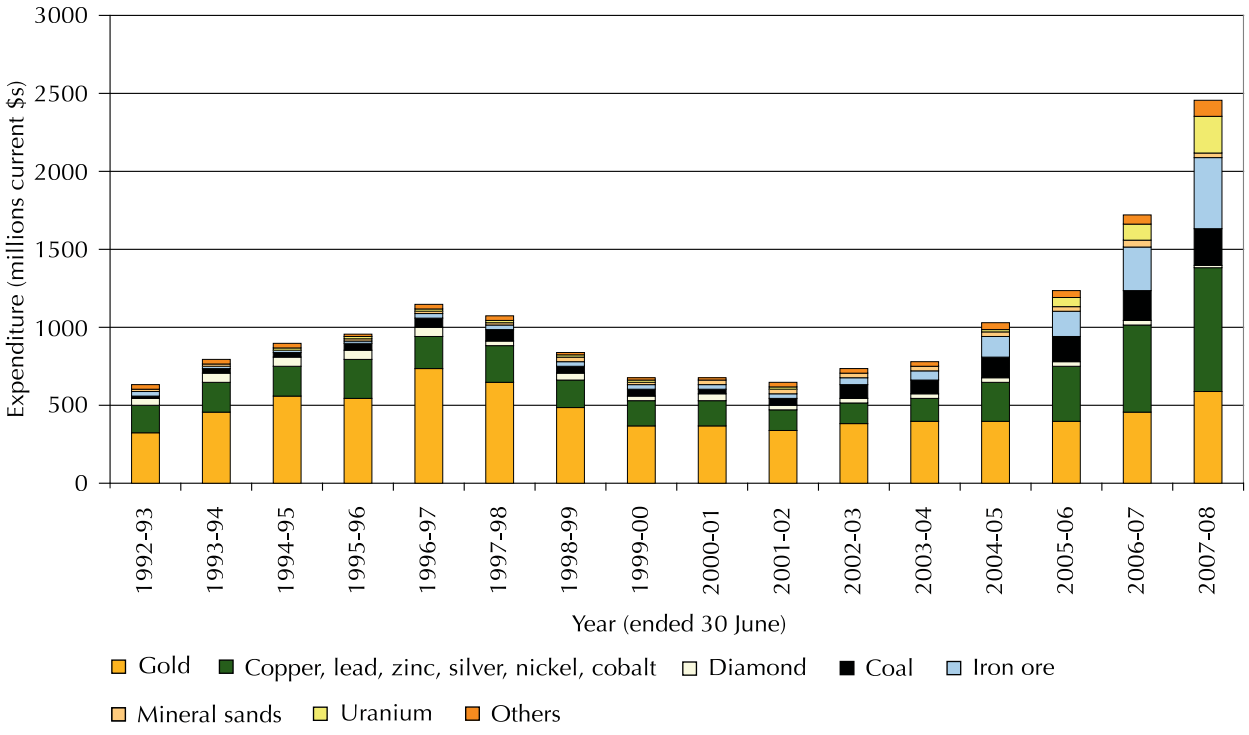
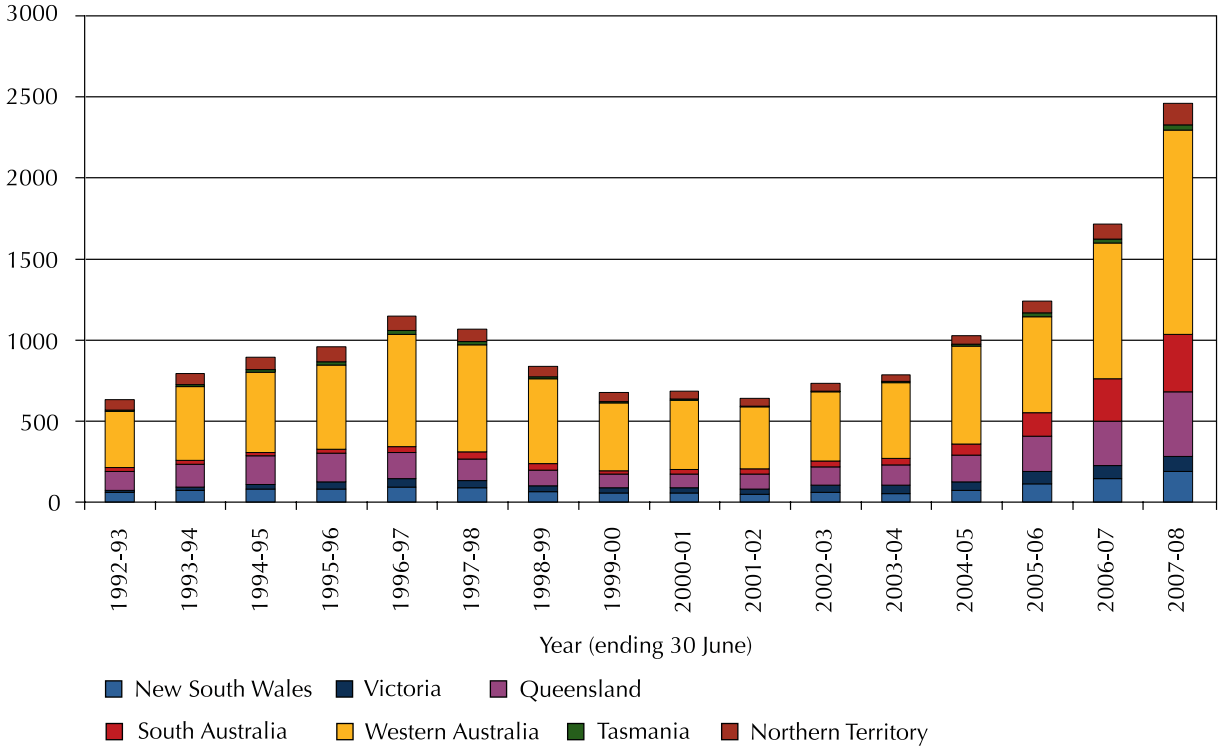


Figure 5. Australian mineral exploration spending by State (Source: ABS)



Spending increased to record levels in all jurisdictions in 2007-08 (Fig. 5). Western Australia was still dominant attracting a record $1259.8 million. Record spending was reported in Queensland which was up 46.1% to $397.8 million, South Australia, up 36.2% to $355.2 million, New South Wales, up 31.8% to $189.9 million, Victoria, up 13.6% to $93.7 million, the Northern Territory, up 43.9% to $132.7 million and in Tasmania where spending rose by 36.7% to $32.4 million.

Exploration Stage

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

ABS survey data of spending showed that, nationally, 41.1% of spending was on exploration for new deposits, compared to 35.6% in 2006-07. Victoria (51.2%) had the highest proportion of its exploration directed to the search for new deposits while Queensland had the lowest at 32.2%. The national share of exploration for new deposits is slightly higher than the Metals Economics Group (MEG) world survey of non-ferrous minerals exploration budgets for 2008 which found that 40% of those budgets in Australia was for grassroots exploration.

Exploration Drilling

In 2007–08, ABS reported that exploration drilling totalled 9.756 million metres, an increase of 1.301 million metres from 2006–07. Drilling in the search for both new deposits and on existing deposits increased significantly in 2007-08. Drilling in search of new mineralisation increased by 680 000 metres to reach a total of 3.92 million metres. Drilling on existing deposits rose by 621 000 metres to a total of 5.836 million metres.

In 2008 some 49 initial public offerings (IPO) on the Australian Securities Exchange were fully or partially for mineral exploration in Australia. This represented a substantial reduction on the 122 listings in 2007. The major listing in 2008 was Ivanhoe Australia Ltd which raised $125 million out of the total minerals IPO raisings of $486 million.

Calendar Year 2008

On a calendar year basis, exploration spending in 2008 rose by 27% to $2608.3 million.

Strong growth in the calendar year resulted from substantial increases in spending in each quarter. This growth reflects strong and growing demand for many commodities particularly from China. However, the initial impact of the global financial crisis began in the December quarter when, although there was growth compared to the December quarter 2007, it was only 3%, significantly lower than the annual percentage increase of 27%.

In 2008, iron ore surpassed gold as the predominant commodity explored for in Australia. Spending on iron ore exploration accounted for 22.4% ($583 million) of total exploration spending while gold's share fell to 21.9% ($569.9 million). As a group, the base metals attracted the largest spending in 2008 with $750.1 million. Spending on the individual commodities in the base metals group in 2008 was: copper $293 million; lead-zinc-silver $133.1 million and nickel-cobalt $324 million. Uranium exploration spending rose from $181.4 million in 2007 to $220.5 million in 2008, reflecting the increasing activity of the large number of new companies floated in recent years specifically to explore for uranium. After a slight fall in 2007, coal exploration spending recovered strongly in 2008 to rise by 43% to $276.3 million.

The Northern Territory and all States, except South Australia, recorded increased exploration spending in calendar year 2008. Western Australia remained dominant with an increase of $361.1 million to $1400.4 million which allowed the State to slightly increase its share of national spending to 53.7% during 2008.

Exploration Outcomes

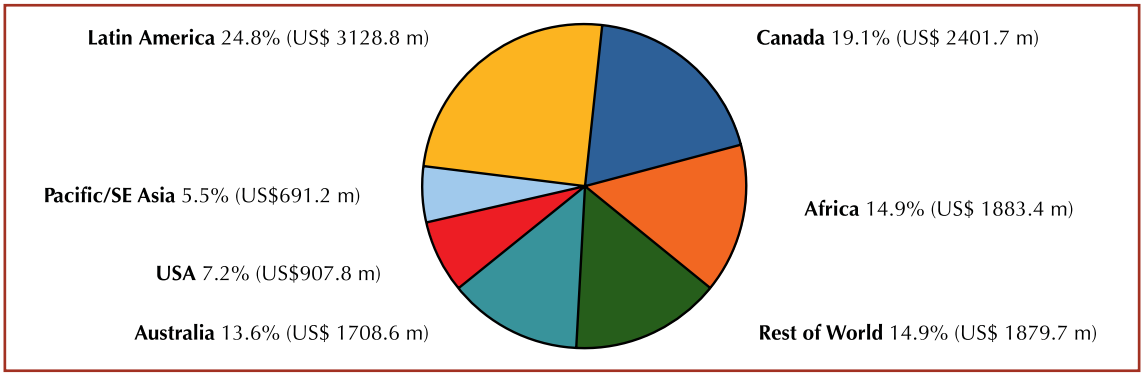
The ongoing strong exploration activity resulted in a very large number of reported intersections of economic grade and several new discoveries. A major review of the highlights of mineral exploration in Australia in 2008 is available in the document *"Australian Mineral Exploration: A Review of Exploration for the Year 2008 - Extended Edition"* available for download from the Geoscience Australia website.

Responding to world demand, there was substantial activity in the iron ore sector with new resources and drilling results released for many smaller deposits and prospects. Similarly, uranium exploration surged as the large number of new companies with a focus on uranium floated in recent years built up their exploration programs.

World Exploration

The MEG survey of world non-ferrous mineral exploration budgets for 2008 reported an increase of 26% to a record estimated total budget of US$13.2 billion. MEG included uranium in the survey for the first time in 2007 and it estimated that, including uranium, world budgets for non-ferrous mineral exploration in 2008 was US$14.4 billion. Of the total, including uranium, US$1976.9 million was directed to exploration in Australia. Excluding uranium, Australia's share of global non-ferrous mineral exploration budgets rose from 11.9% in 2007 to 13.6% in 2008 and Australia retained its position as the country with the second highest share of budgets after Canada (19%) (Fig. 6).

Figure 6. Distribution of world non-ferrous mineral exploration budgets (excluding uranium) as reported by companies, 2008 (Source: Metals Economics Group).



According to the MEG survey, 56% of the 2008 non-ferrous mineral exploration budgets for Australian-based companies was for exploration in Australia. The survey included 519 companies with non-ferrous exploration budgets of more than US$100 000 which were exploring in Australia. Budgets for Australian non-ferrous mineral exploration included gold (US$700.4 million) and base metals (US$824.5 million). World uranium exploration budgets in 2008 totalled US$1150.8 million of which Australia received 23% (US$265 million), making it the second largest after Canada which received 38%. `

Outlook for Exploration

Both world and domestic mineral exploration levels grew strongly in 2008 on the back of continuing strong world demand, especially from China. With the world financial crisis beginning to be felt by the end of 2008 and the lower demand being registered along with lower prices, the outlook for exploration suggests a significant contraction is likely, both in Australia and world-wide. The continuing high price for gold is conducive to reasonable levels of gold exploration being maintained in 2009. The outlook for iron ore exploration remains reasonably bright, although it is likely to retreat from the highs of 2008. The degree of growth in the Chinese economy will be a key driver, along with gold price, of the level of exploration spending in Australia.

Overall, the outlook for exploration has softened.

Offshore Mineral Exploration in Commonwealth Waters

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The Commonwealth ***Offshore Minerals Act 1994*** regulates the exploration for, and the production of minerals other than petroleum over the continental shelf three nautical miles beyond the territorial baseline (generally the low water mark) of the States and Territories. The administration is shared between the Commonwealth and the States and the Northern Territory (NT). The Joint Authority consists of the relevant Commonwealth minister and the State/NT minister and is responsible for major decisions such as grants and refusals. The State/NT minister is called the Designated Authority and is responsible for the day-to-day administration of the Act.

Applications for a mineral exploration licence (MEL) are made to the Designated Authority. The initial term of a licence is four years and it may be renewed for up to three two year periods, subject to satisfactory performance of the licence conditions. There is a mandatory reduction of 50% of the licence area on renewal of an MEL.

To May 2009, a total of 82 offshore MEL applications had been received since February 1990. Currently there are two active licences, T-2-MRL (Mineral Retention Licence) and T-3-MEL, both in Ringarooma Bay in north east Tasmania. The Mineral Retention Licence owner, **Van Dieman Mines plc**, was placed in administration in February 2009. Prior to being placed in administration, the company was investigating the viability of mining an offshore tin and sapphire deposit and operated an onshore alluvial mine at the Scotia tin deposit. **Mineral Holdings Australia** is exploring for similar minerals within T-3-MEL.

An **Australian Offshore Minerals Locations** map showing mineral occurrences and deposits within Australia's 200 nautical mile exclusive economic zone and extended continental shelf is available from the Geoscience Australia Sales Centre sales@ga.gov.au or as a free download* on the Geoscience Australia website. The Australian Offshore Mineral Locations data also can be viewed online by using Geoscience Australia's **Australian Marine Spatial Information System** (AMSIS).

** http://www.ga.gov.au/minerals/exploration/offshore/*

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

CBM coal bed methane

CMM coal mine methane

CSG coal seam gas

CSM coal seam methane

cpht carats per hundred tonne

CSIRO Commonwealth Scientific and Industrial Research Organisation

EDR Economic Demonstrated Resources

GIS geographical information system

g grams

g/t grams per tonne

GL gigalitre

Gt gigatonne

IAEA International Atomic Energy Agency

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

kg kilogram

km kilometre

kt kilotonne (thousand tonnes)

ktpa kilotonne per annum

L litre

lbs pounds

LNG liquefied natural gas

m metre

m3 cubic metre

Mc million carats

MEL mineral exploration licence

ML million litres

Mlbs million pounds

mm millimetre

Mozs million ounces

Mt million tonnes

Mtpa million tonnes per annum

MW megawatt

MWh megawatt hour

na not available

NSW New South Wales

NT Northern Territory

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

ozs ounces

PDR Paramarginal Demonstrated Resources

PGM platinum-group metals

PJ petajoules

ppm parts per million

Qld Queensland

RAR Reasonably Assured Resources

REO rare earth oxide

REE rare earth element

ROM run-of-mine

SA South Australia

SDR Subeconomic Demonstrated Resources

t tonne

Tas Tasmania

tpa tonnes per annum

U uranium

U_3O_8 uranium oxide

USA United States of America

USGS United States Geological Survey

US$ United States of America dollar

Vic Victoria

WA Western Australia

$1 M million dollars

Appendix 2

National Classification System for Identified Mineral Resources (2009 edition)

INTRODUCTION

Australia's mineral resources are an important component of its wealth, and a long term perspective of what is likely to be available for mining is a prerequisite for formulating sound policies on resources and land-access.

In 1975, Australia (through the Bureau of Mineral Resources, which has evolved to become Geoscience Australia) adopted with minor changes the McKelvey resource classification system used in the United States by the then Bureau of Mines and the US Geological Survey (USGS). Australia's national system remains comparable with the current USGS system, as published in its *Mineral Commodity Summaries*.

Companies listed on the Australian Securities Exchange are required to report publicly on Ore Reserves and Mineral Resources under their control, using the Joint Ore Reserves Committee (JORC) Code (see http://www.jorc.org/). This has also evolved from the McKelvey system, so the national system and JORC code are compatible. Data reported for individual deposits by mining companies are compiled in Geoscience Australia's national mineral resources database and used in the preparation of the annual national assessments of Australia's mineral resources.

Estimating the total amount of each commodity likely to be available for mining in the long term is not a precise science. For mineral commodities, the long term perspective takes account of the following:

- JORC Code Reserves will, in general, all be mined, but they only provide a short term view of what is likely to be available for mining.
- Most current JORC Code Measured and Indicated Resources are also likely to be mined.
- Some current JORC Code Inferred Resources will also be transferred to 'Reserves'; and
- New discoveries will add to the resource inventory.

CLASSIFICATION PRINCIPLES

The national system for classification of Australia's identified mineral resources is illustrated in **Figure A1**. It classifies Identified (known) Mineral Resources according to two parameters, the degree of geological assurance and the degree of economic feasibility of exploitation. The former takes account of information on quantity (tonnage) and grade while the latter takes account of economic factors such as commodity prices, operating costs, capital costs, and discount rates.

Resources are classified in accordance with economic circumstances at the time of estimation. Resources which are not available for development at the time of classification because of legal and/or land access factors are classified without regard to such factors, because circumstances could change in the future. However, wherever possible, the amount of resource affected by these factors is stated.

Because of its specific use in the JORC Code, the term 'Reserve' is not used in the national inventory, where the highest category is '**Economic Demonstrated Resources**' (EDR, Figure A1). In essence, EDR combines the JORC Code categories 'Proved Reserves', Probable Reserves', plus 'Measured Resources' and 'Indicated Resources' as shown in Figure A2. This is considered to provide a reasonable and objective estimate of what is likely to be available for mining in the long term.

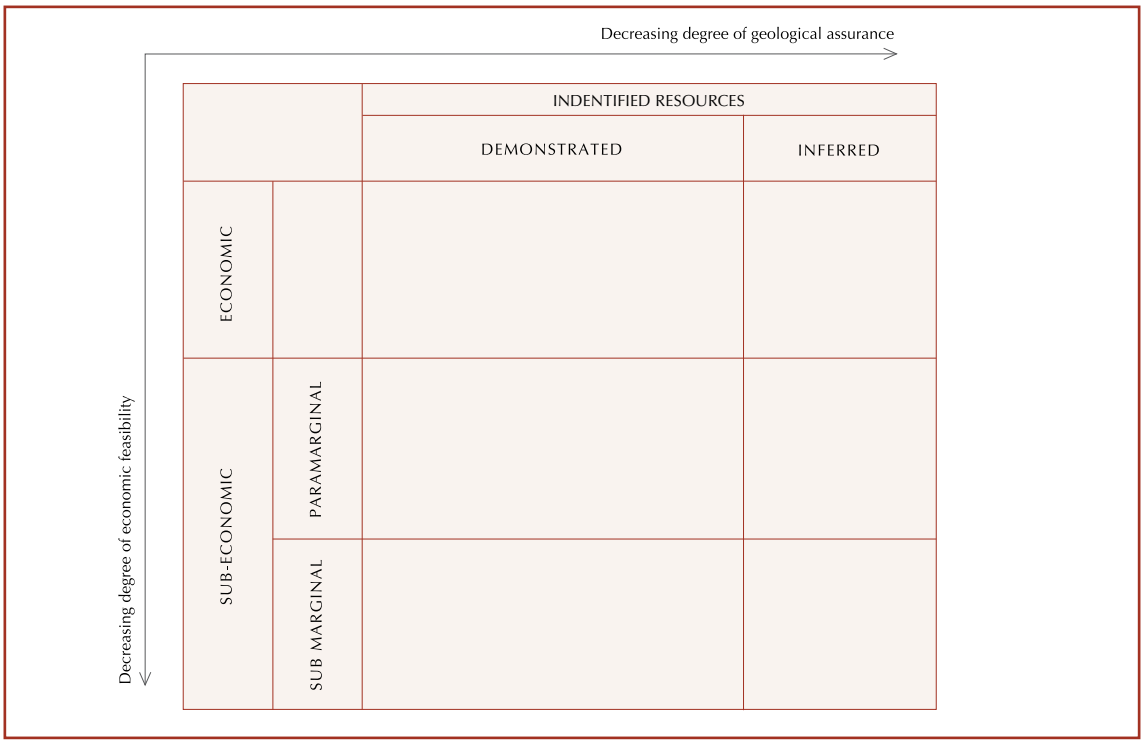

Figure A1. Australia's national classification system for mineral resources.

TERMINOLOGY AND DEFINITIONS FOR AUSTRALIA'S NATIONAL SYSTEM

Resource: A concentration of naturally occurring solid, liquid or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially (within a 20-25 year timeframe) feasible.

The definition does not intend to imply that exploitation of any such material will take place within that time span, but that exploitation might reasonably be considered. It should be applied also on a commodity by commodity basis to take account of prevailing and prospective technologies. The term includes, where appropriate, material such as tailings and slags. Mineralisation falling outside the definition of 'Resource' is referred to as an 'occurrence' and is not included in the national inventory.

Identified Resource: A specific body of mineral-bearing material whose location, quantity, and quality are known from specific measurements or estimates from geological evidence for which economic extraction is presently or potentially feasible.

CATEGORIES BASED ON DEGREE OF GEOLOGICAL ASSURANCE OF OCCURRENCE

To reflect degrees of geological assurance, Identified Resources are divided into Demonstrated Resources and Inferred Resources:

1 'Demonstrated Resource': A collective term used in the national inventory for the sum of 'Measured Mineral Resources', 'Indicated Mineral Resources' 'Proved Ore Reserves' and 'Probable Ore Reserves' (see Figure A2), which are all defined according to the JORC Code:

- A **'Measured Mineral Resource'** is that part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a high level of confidence. It is based on detailed and reliable exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes. The locations are spaced closely enough to confirm geological and grade continuity.
- An **'Indicated Mineral Resource'** is that part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a reasonable

level of confidence. It is based on exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes. The locations are too widely or inappropriately spaced to confirm geological and/or grade continuity but are spaced closely enough for continuity to be assumed.

- A **'Proved Ore Reserve'** is the economically mineable part of a Measured Mineral Resource. It includes diluting materials and allowances for losses which may occur when the material is mined. Appropriate assessments and studies have been carried out, and include consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction could reasonably be justified.
- A **'Probable Ore Reserve'** is the economically mineable part of an Indicated, and in some circumstances, a Measured Mineral Resource. It includes diluting materials and allowances for losses which may occur when the material is mined. Appropriate assessments and studies have been carried out, and include consideration of and modification by realistically assumed mining, metallurgical, economic, marketing, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that extraction could reasonably be justified.

2 An **'Inferred Mineral Resource':** is that part of a Mineral Resource for which tonnage, grade and mineral content can be estimated with a low level of confidence. It is inferred from geological evidence and assumed but not verified geological and/or grade continuity. It is based on information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes which may be limited or of uncertain quality and reliability.

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 the economics cannot be determined, these Inferred Resources are shown as 'undifferentiated'.

CATEGORIES BASED ON ECONOMIC FEASIBILITY

Identified resources include economic and subeconomic components.

1. **'Economic'** 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.

2. **'Subeconomic'** 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, could be produced given postulated limited increases in commodity prices or cost-reducing advances in technology. The main characteristics of this category are economic uncertainty and/or failure (albeit just) to meet the criteria for economic.
- **'Submarginal'** That part of Subeconomic Resources that would require a substantially higher commodity price or major cost-reducing advance in technology, to render them economic.

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 are included in the economic resources category irrespective of whether or not exploitation is commercially practical. It is also assumed that producers or potential producers will receive the 'going market price' for their production.

The information required to make assessments of the economic viability of a particular deposit is commercially sensitive. Geoscience Australia's assessment of what is likely to be economic over the long term must take account of postulated price and cost variations. Economic resources include resources in enterprises which are operating or are committed, plus undeveloped resources which are judged to be economic on the basis of a realistic financial analysis, or compare with similar types of deposits in operating mines.

How is the national inventory compiled?

Virtually all of the mineral resource estimates compiled by Geoscience Australia's commodity specialists, including Subeconomic Resources, originate from published mining company sources reporting under the JORC Code. Given the common resource categories and definitions, the transfer of mineral resources from company reports into Australia's national mineral resource categories is quite straightforward, as summarised in **Figure A2**.

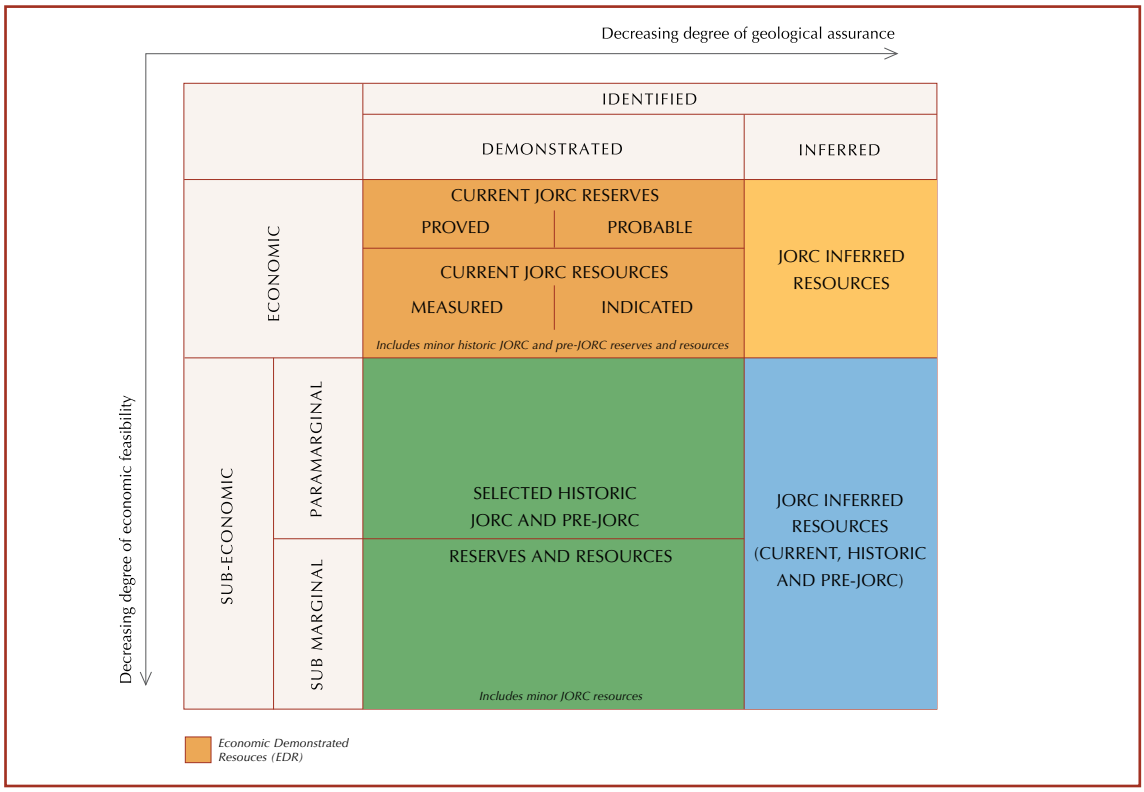

Figure A2. Correlation of JORC Code mineral resource categories with Australia's national mineral resource classification system.

Notes for figure A2

(i) EDR comprise mainly current JORC Code reserves and resources, but minor proportions of EDR come from selected historic JORC Code and pre-JORC Code reserves and resources;

(ii) In some instances, where a deposit is reported as having Measured and/or Indicated Resources, particularly where there are no Reserves reported, a professional judgement is made by Geoscience Australia as to whether all or part of the reported Resources are included in EDR, or assessed as subeconomic; and

(iii) Subeconomic Resources are largely from historic company reports but are still the most recent estimates, and it also includes minor proportions of resources from current company reports which are JORC Code compliant but have been assessed by Geoscience Australia as subeconomic.

In essence, for the reasons outlined above, the national inventory is compiled by:

- Incorporating the JORC Code Proved and Probable Ore Reserves and Measured and Indicated Mineral Resources into EDR.
- Transferring JORC Code Inferred Resources to the national Inferred Resources category. There is commonly insufficient information to determine whether or not Inferred Resources are economic.

In addition, Geoscience Australia makes decisions on the transfer of historic JORC Code and pre-JORC Code estimates of ore reserves and mineral resources. Some of these old estimates are economically less attractive under current conditions, usually due to lower commodity prices and/or unforeseen technical problems. Some of these resources may be removed from EDR and transferred to Paramarginal or Submarginal Resources. However, if such resources cannot be reasonably expected to become economic within a time frame of 20 to 25 years, they are removed from the national mineral resources database.

Companies report grade and tonnage data for individual deposits. However, it is not meaningful to add up grades and tonnages from different deposits, so the national inventory reports only the aggregated total tonnage for each commodity – that is, the sum of the contained metal in individual deposits for each resource category which has been derived from company reports.

Allowances for losses

For resource categories of the national classification system, allowances for losses as a result of mining and milling are the same as those for corresponding categories in the JORC Code. The allowances for losses, which apply to all minerals except coal, uranium, thorium and oil shale, are summarised as follows:

National system	JORC system	Mining losses	Milling losses
Demonstrated Resources (Measured)	Proved Ore Reserves	deducted	not deducted - but are considered in assessing economic viability
	Measured Mineral Resources	not deducted	not deducted
Demonstrated Resources (Indicated)	Probable Ore Reserves	deducted	not deducted - but are considered in assessing economic viability
	Indicated Mineral Resources	not deducted	not deducted
Inferred Resources	Inferred Resources	not deducted	not deducted

Exceptions

(i) For **coal**, different terms are used – 'Recoverable coal resources' makes allowance for mining losses only. 'Saleable coal' makes allowance for mining as well as processing losses.

(ii) **Uranium and thorium** resources are reported with losses resulting from mining and milling deducted from all categories, consistent with the international uranium resource classification system of the OECD Nuclear Energy Agency and International Atomic Energy Agency.

(iii) **Oil Shale** resources are reported as recoverable oil.

Appendix 3

Staff and Commodity Responsibilities: AIMR 2009 and Related Projects

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MINERAL RESOURCES PROJECT

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