



Australian Government
Geoscience Australia

AUSTRALIA'S IDENTIFIED MINERAL RESOURCES 2010



**Australian Government
Geoscience Australia**

Resources, Energy and Tourism Portfolio

Minister for Resources, Energy and Tourism: the Hon. Martin Ferguson AM, MP

Geoscience Australia

Chief Executive Officer: Dr Chris Pigram



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For further information on this publication and Australia's mineral resources please email minerals@ga.gov.au

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FRONT COVER: Iron ore mining operation at Marandoo mine, Western Australia (Rio Tinto Iron Ore).

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Executive Summary

Australia's Identified Mineral Resources is an annual nation-wide assessment which takes a long term view of mineral resources likely to be available for mining. The highest category in the national inventory is Economic Demonstrated Resources (EDR), which in essence, combines the Joint Ore Reserve Committee (JORC) Code categories of ore reserves and most of the Measured and Indicated Resources. JORC Code ore reserves of commodities are included for comparison, which provide a short to medium-term view of mineral stocks. The assessment also includes evaluations of long-term trends in mineral resources, world rankings, summaries of significant exploration results, brief reviews of mining industry developments and an analysis of mineral exploration expenditure across Australia.

Australia's EDR for the following 16 mineral commodities increased during 2009 — black coal, copper, diamonds, gold, iron ore, lead, lithium, molybdenum, phosphate rock, silver, tin, tungsten, uranium, vanadium, zinc, and zircon. However, during the same period there was a decrease in the EDR for eight commodities, brown coal, cobalt, magnesite, ilmenite, rutile, nickel, platinum group elements and rare earth oxides. EDR for antimony, bauxite, cadmium, manganese ore, niobium, shale oil, and tantalum remained at levels similar to those reported in 2008.

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

Australia's EDR of bauxite were estimated to be 6.2 gigatonnes (Gt) in 2009, which ranks second largest in the world behind the Republic of Guinea. 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. Despite the global financial crisis, large companies have maintained overall production levels. New bauxite mining proposals continue to be advanced, such as Bauxite Resources Limited's Bindoon direct shipping ore project in WA and Rio Tinto Alcan's South of the Embley project in Qld. Steadily increasing interest and investment from China has accelerated changes in Australia's bauxite exploration, mining and processing industries in recent years.

Recoverable EDR of **black coal** in 2009 increased 11.5% to 43.8Gt which represents 7% of the world's economic recoverable black coal resources and ranks Australia as having the world's fifth largest resources. Qld (58%) and New South Wales (NSW) (38%) had the largest share of recoverable EDR in Australia. The Bowen Basin in Qld contains 35% of Australia's recoverable EDR of black coal and the Sydney Basin in NSW contains 31%.

Recoverable EDR of **brown coal** in 2009 was 37.1Gt, slightly less than 2008 and represents about 25% of the world's recoverable brown coal, it remained the largest of any country. All of Australia's brown coal EDR occurs in Victoria (Vic) with about 93% of the total located in the Latrobe Valley.

Coal seam gas is reported as proven and probable reserves (2P) under the Society of Petroleum Engineers—Petroleum Resources Management System. At December 2009 coal seam gas reserves were 26 132 Petajoules (PJ), an increase of 61.5% over the 2P reserves at December 2008. Queensland has 23 038 PJ (or 88.1% of the 2P reserves) with the remaining 3094 PJ in NSW.

Australia's EDR of **copper** rose by 2.5 million tonnes (Mt) in 2009 to 80.4Mt, an increase of 3% with most of the increase in NSW. South Australia (SA) has the largest EDR at 56.5Mt, which is 70% of the national total and mainly in the Olympic Dam deposit. In 2009, copper production fell by 4% and spending on exploration for copper fell by 54%. Production commenced at Prominent Hill (SA) early in 2009 and studies continued through 2009 into major development proposals at Olympic Dam, Cadia East (NSW) and Ernest Henry (Qld).

Gold mining and exploration occurs in all States and the Northern Territory (NT). Australia's EDR of gold rose by 18% to 7399 tonnes in 2009, while production increased 3.5% to 223 tonnes. Western Australia (40%, 2980 tonnes), SA (31%, 2299 tonnes) and NSW (20%, 1487 tonnes) collectively account for more than 90% of national gold EDR. Approximate world resource figures provided by the United States Geological Survey (USGS) suggest that Australia's EDR for gold compares favourably with those of South Africa (6000 tonnes) and Russia (5000 tonnes), the other countries with the highest economic resource figures. During 2009 exploration spending on gold in Australia fell by about 19% to \$463.3 million and its share of total exploration spending in Australia was 23%

In 2009, EDR of **iron ore** increased by 16.7% to 28Gt, which is about 17% of world economic resources and the world's second largest. Western Australia has 98% of Australia's EDR with about 81% occurring in the Pilbara region. Iron ore exploration expenditure in 2009 totalled \$521.2 million, a 10.6% decrease on the \$583 million spent during 2008. Iron ore exploration accounted for 25.8% of total mineral exploration expenditure in 2009.

Australia's **lithium** EDR increased by 4% in 2009 to 607 kilotonnes (kt) which is about 8% of world economic resources and ranks Australia as the world's third largest behind Chile and Argentina. All EDR occur in WA, which has the world's largest and highest grade spodumene deposit at the Mount Cattlin mine.

Australia's EDR of **manganese ore** in 2009 totalled 181Mt, which was unchanged from 2008 and represents about 13% of the world's economic resources of manganese ore, the world's fourth largest. Groote Eylandt deposit in the NT contains 68% of Australia's 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). In 2009, EDR of ilmenite and rutile decreased by 5.6% to 200.4Mt, and by 0.9% to 22.7Mt respectively. However, EDR of zircon increased by 2.3% to 40Mt. Rutile and zircon resources rank first in the world while ilmenite resources are the second largest worldwide. The full impact of the global financial crisis on the demand for heavy mineral sand products was felt in 2009. According to Iluka Resources Ltd, global consumption of high grade titanium feedstocks was estimated to have fallen by 20% in 2009 although there were signs of recovery in the second half of 2009 and rebuilding of inventories is expected in 2010. Similarly, there was a reduction of about 25% in global demand for zircon in 2009. Iluka concluded that mineral sand commodity prices would have to be significantly higher to support new mineral sand projects.

Australia's EDR of **nickel**, which at 35% is the world's largest, decreased by 9.1% from 26.4Mt in 2008 to 24Mt in 2009. Western Australia remains the largest holder of nickel resources with 90.9% of total Australian EDR, comprising both sulphide and lateritic deposits. Although nickel prices recovered during 2009 leading to increased production, some nickel mines were closed and others placed on care and maintenance.

Australia's EDR of **rare earth oxides** in 2009 were 1.65Mt, unchanged from 2008. 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 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** totalled 51kt in 2009, unchanged from 2008 and ranking it the second largest in the world. All of the EDR are located in WA with more than 98% associated with two deposits. Mining at Talison Minerals' Wodgina mine in WA remained suspended throughout 2009 because of a fall in demand for Australia's tantalum.

Australia's EDR of **tin** increased by 21% to 176kt in 2009, ranking Australia as the world's eighth largest. The bulk of the EDR occur in Tasmania (Tas) and Qld.

Australia's EDR of **tungsten** increased by 75% in 2009 to 195.5kt, ranking it the third largest with 7% of the world's economic resources. The bulk of the EDR occurs in Tas with 61% followed by Qld with 27%. The decline in tungsten prices to below US\$200 per metric tonne unit and the strengthening of the Australia dollar relative to the US dollar had an adverse impact on the economic viability of a number of Australian projects.

Australia prepares uranium estimates within the international scheme of the Organisation for Economic Cooperation and Development Nuclear Energy Agency and the International Atomic Energy Agency (the NEA/IAEA). Australia's Reasonably Assured Resources (RAR) of **uranium** recoverable at less than US\$80 per kilogram of uranium (equates to EDR) at December 2009 were estimated to be 1.223Mt, an increase of 5% during the year. This was the result of increase in resources for the Olympic Dam deposit (SA) and smaller increases at the Four Mile deposit (SA). Australia has the world's largest uranium resources and accounts for more than 45% of world resources in this category. Approximately 90% of Australia's total RAR of uranium recoverable at less than US\$80

per kilogram of uranium are in six main deposits, Olympic Dam (the world's largest uranium deposit), Ranger, Jabiluka and Koongarra in the Alligator Rivers region of NT, Kintyre and Yeelirrie in WA.

Australia's total resources of **zinc, lead and silver** rose only marginally in 2009. Weak zinc and lead prices saw decreased production for 2009, with several mines on care and maintenance during the year. Of those that remained in operation most pursued a high-grade, lower tonnage plan, with reduced workforce and lower expenditure. Zinc-lead exploration for 2009 was 64% less than the previous year and many mine development activities remained on hold. Towards the end of 2009, several zinc-lead mines embarked on plans to increase tonnage, reopen infrastructure and resume development or exploration in anticipation of a continuing recovery of zinc and lead prices through 2010. Australia's EDR of zinc, lead, and silver totalled 55.9Mt, 29.4Mt, and 69.4kt respectively in 2009 and was ranked the largest economic resources in the world.

Australia's **vanadium** EDR rose by 53% in 2009 to 2673kt, and was ranked as the world's fourth largest resources. The bulk of Australia's resources are located in WA. The fluctuation in prices and the nature of the market for vanadium which can be sourced from secondary supplies, have had a significant impact on the development of Australian vanadium deposits.

During 2009 and 2010 there was considerable interest worldwide in **potash** resources and mining. In August 2010, BHP Billiton made an offer to acquire all of the issued and outstanding common shares of Potash Corporation of Saskatchewan Incorporated, the world's largest producer of potash. The offer was subsequently withdrawn in November 2010. Potash is a generic term covering a variety of potassium-bearing ores, minerals and refined products. The most important potash ore is sylvinite, a mixture of potassium chloride and sodium chloride, which is used in the production of fertilisers. Potash is not mined in Australia, which has only modest resources by world standards. Australia's fertiliser requirements are met through phosphate rock production and imports of potassium fertiliser. Imports vary between 300 to 460kt of potassium fertiliser each year valued at \$355 million for 2008–09. There has been an increase in potash exploration in Australia in recent years.

In Australia, **exploration expenditure** in 2009 fell by 22% to \$2023 million as the results of reduced world demand for commodities caused by the world economic crisis. However, with iron ore and coal being significant components in its exploration spectrum the impact on Australia was not as severe as that experienced in other countries.

While the reduction in exploration spending in 2009 was substantial, it was a year of two halves with substantial reductions in the March and June quarters being moderated by lower reductions in the September and December quarters. The falls in the March and June quarters were 25.8% and 33.6% respectively. However, in the September and December quarters the rate of reduction slowed considerably with falls of 19% and 10.7% respectively. This slowing suggests that the impact of the global financial crisis was moderating by the end of 2009.

With the gradual improvement in the world economic situation and the continued strong demand for bulk commodities from Asia, the outlook for mineral exploration in Australia is likely to resume growth in 2010. If the continued high price of gold is maintained, or increased further, investment in gold exploration should add further impetus to exploration overall.

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 2009 there has been a significant trend towards lower AEDR/production ratio for coal and iron ore, which was the result of major increases in production and reassessment of resources.

Commodities with resource life of less than 50 years are diamonds (about 20 years at current rates of production), manganese ore (20 years), gold (30 years), zinc (45 years) and silver (45 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 competitive and globalised commodity market, multinational mining companies are continually seeking mineral deposits which will provide 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 the location and scale of competitor projects. Individual mine projects in Australia will be ranked by multinational companies 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 to make them competitive on the world market, as well as 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. The data are reproduced by the Australian Bureau of Statistics.

Australia's Identified Mineral Resources 2010 presents estimates of Australia's mineral resources at end of December 2009 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 figures from the Australian Bureau of Agricultural and Resource Economics and Sciences. 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 2010 provides information on and analysis of mineral exploration expenditures in Australia for 2008–09 and the calendar year 2009. 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 shows how mineral resources reported by companies under the *Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves* (referred to as the Joint Ore Reserve Committee (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 Economic Demonstrated Resources (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 and 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 (AEDR) 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 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 ore reserves/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 ore reserves/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; m³ = cubic metre; L = litre; kt = 10³t; Mc = 10⁶ carat; Mt = 10⁶t; Gt = 10⁹t; GL = 10⁹L; n.a. = not available.

- | | |
|---|---|
| <ul style="list-style-type: none"> 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 and Sciences (ABARES). e) Sources: Geoscience Australia for Australian figures, USGS Mineral Commodities Summaries for other countries. f) World mine production for 2009, 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) Source: Western Australian Department of Mines and Petroleum. l) Excludes Morocco and USA. m) 197 482 t of spodumene concentrate (Source: Western Australian Department of Mines and Petroleum). n) Excludes USA. | <ul style="list-style-type: none"> o) Production for 2008–09 (Source: Department of Mines and Energy, Geological Survey of Queensland). p) Not reported by mining companies. q) Duchess mine (Qld) produced 1.957 million t phosphate rock in 2008–09. Christmas Island produced 420 205 t phosphate rock and 42 300 t phosphate dust in 2009. r) Total Inferred Resource excludes a 'total potential' shale oil resource of the Toolebuc Formation, Queensland of 245 000 GL that was estimated by Geoscience Australia's predecessor, the Bureau of Mineral Resources, and CSIRO in 1983. s) Source: World Energy Council (WEC) Survey of Energy Resources 2010. t) Latest production figures for end 2008 from WEC Survey of Energy Resources 2010. u) 0.105 kt of tantalite (Source: Western Australian Department of Mines and Petroleum) containing approx. 0.022 kt Ta. v) Thorium resources reduced by 10 percent to account for mining and processing losses. w) Source: OECD/NEA & IAEA (2009). Compiled from the most recent data for resources recoverable at costs of less than US\$80/kg U. x) Source: World Nuclear Association. y) 74 789 t of chromite expressed as Cr₂O₃ (Source: Western Australian Department of Mines and Petroleum). z) World production of 23 000 000 t of 'marketable chromite ore' as reported by USGS. <p>** = Cadmium production as at 31 December 2008.</p> |
|---|---|

Table 1. Australia's resources of major minerals and world figures as at December 2009.

COMMODITY	UNIT	AUSTRALIA							WORLD	
		Demonstrated Resources			Inferred Resources (a)	Accessible EDR (b)	JORC Reserves (% of AEDR) (c)	Mine Production 2009 (d)	Economic Resources (e)	Mine Production 2009 (f)
		Economic (EDR)	Subeconomic							
	Para-marginal		Sub-marginal							
Antimony	kt Sb	61	17	24	226	61	42 (69%)	0.2(i)	2100	187
Bauxite	Gt	6.2	0.2	1.4	0.93	5.4	2.4 (44%)	0.065	27	0.201(e)
Black coal										
in situ	Gt	60.7	3.3	9.2	125.2					
recoverable	Gt	43.8	1.8	5.9	78.2	43.7	14.2(g) (33%)	0.445	669(i)	5.8(i)(j)
Brown coal										
in situ	Gt	41.2	43.5	18.1	112.4					
recoverable	Gt	37.1	39.1	16.3	101.2	32.1	4.7(g) (15%)	0.068(i)	148(i)	0.88(i)
Cadmium	kt Cd	60.8	10.0	10.2	0.3	60.8	51.3 (84%)	0.46**	490	19.9(n)
Cobalt	kt Co	1363	269	241	1471	1363	293 (22%)	4.63(k)	6467	60.13
Copper	Mt Cu	80.4	4.5	1.0	38.4	80.4	23.2 (29%)	0.853	596	15.8
Chromium	kt Cr	0	0	0	3455	0	0	46.3(y)	>97 500	(z)
Diamond										
gem & near gem	Mc	104.8	41.7	0	15.3	104.8	85.5 (82%)	5.3	n.a.	96
industrial	Mc	109.1	43.4	0	16	109.1	89 (82%)	5.5	594	63
Fluorine	Mt F		0.5	0	0.4	0	0	0	117(l)	2.6
Gold	t Au	7399	1495	120	4431	7270	3548 (48%)	223	47 00	2350
Iron ore	Gt	28.0	0.3	1.9	33.5	37.9	12.3 (44%)	0.394	168	2.3
Lead	Mt Pb	30.8	4.8	0.3	19.1	30.8	11 (35%)	0.57	85	4
Lithium	kt Li	607	0	0.1	37	607	58 (9.5%)	(m)	9927	18(n)
Magnesite	Mt MgCO ₃	330	22	35	826	330	37.5 (11%)	0.345(o)	7980	17.32(n)
Manganese ore	Mt	181	23	167	134	181	146 (81%)	4.45	1420	31
Mineral sands										
Ilmenite	Mt	200.4	30.2	0.03	127.1	167.3	27.7 (17%)	1.534	1252	9.1
Rutile	Mt	22.7	7.0	0.06	31.3	19.4	5.0 (26%)	0.280	46	0.5(n)
Zircon	Mt	40.0	10.3	0.07	34.3	33.6	8.9 (26%)	0.476	87.7	1.19
Molybdenum	kt Mo	276	905	5	263	276	220 (80%)	0	8700	200
Nickel	Mt Ni	24.0	3.0	1.9	21.2	24.0	4.7 (20%)	0.165	68.6	1.4
Niobium	kt Nb	115	15	0	543	115	0	(p)	2900	62
Phosphate rock	Mt	248.6	1014	0	1295	248.6	81.6 (33%)	(q)	16 000	158
PGE (Pt, Pd, Os, Ir, Ru, Rh)	t metal	5.2	132.3	35.3	145.3	0.9	0.12 (13%)	0.726	71 000	373
Rare earths (REO & Y₂O₃)	Mt	1.65	0.37	34.48	24.56	1.65	0	0	95	1.33
Shale oil	GL	0	213	2074	1272(r)	0	0	0	763 139(s)	1.165(t)
Silver	kt Ag	70.3	11.9	2.9	33.7	70.3	26 (37%)	1.63	438	21.2
Tantalum	kt Ta	51	15	0.2	31	51	19 (37%)	0.022(u)	116	0.62
Thorium	kt Th	0	75.7(v)	0	409.0(v)	0	0	0	n.a.	n.a.
Tin	kt Sn	176	63	27	395	176	47 (27%)	5.63	5660	332
Tungsten	kt W	195.5	0.8	1.4	204	195.5	40.3 (20.6%)	0.0036	2995	58
Uranium	kt U	1223	11	3	567	1115	307 (27%)	7.985	2577(w)	50.772(x)
Vanadium	kt V	2673	8629	1279	5117	2673	1172 (44%)	0	15 673	54
Zinc	Mt Zn	58.4	4.2	1.0	21.8	58.4	19.6 (33%)	1.29	235	11.1

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

The trends in Economic Demonstrated Resources (EDR) for Australia's major mineral commodities have undergone significant and sometimes dramatic changes over the period 1975–2009 (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 as a result of 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 from low-grade deposits which previously were uneconomic
- adoption of the Joint Ore Reserve Committee (JORC) Code¹ 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 JORC Code. Many companies re-estimated their mineral resources to comply with the JORC 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 JORC 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 resulted from re-classification of some resources within deposits on Cape York Peninsula to comply with requirements for the JORC Code ('b').

Black Coal

A major re-assessment of New South Wales (NSW) coal resources during 1986 by the New South Wales 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 because of the combined impact of increased rates of mine production and mining companies re-estimating ore reserves and mineral resources more conservatively to comply with requirements of the JORC Code. In 2009 black coal EDR increased significantly mainly because of the discovery and delineation of additional resources as a result of high levels of exploration and through reclassification of resources.

Iron Ore

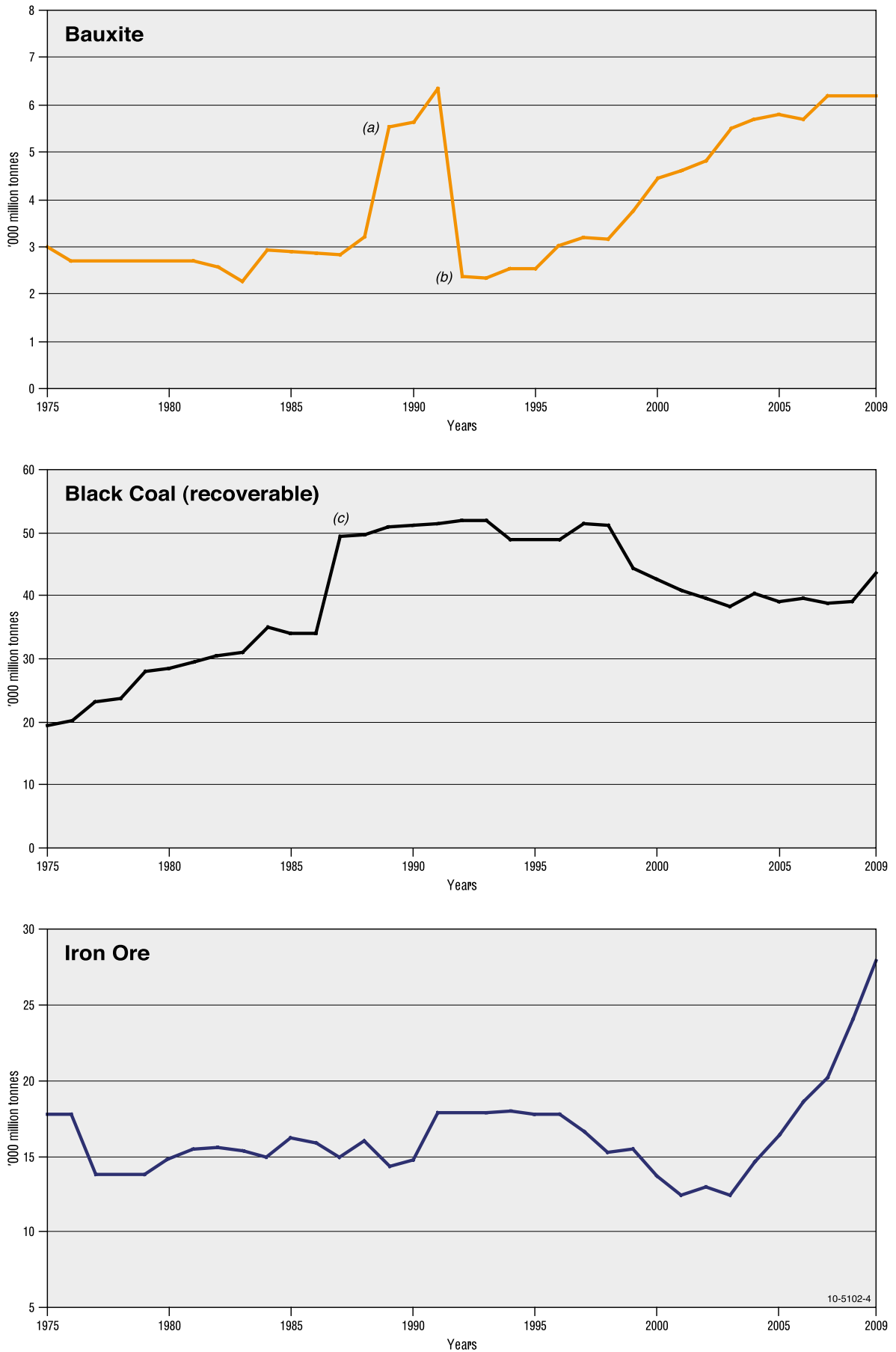
EDR for iron ore declined from 1996 to 2001 because of the combined impacts of mining companies re-estimating ore reserves and mineral resources more conservatively to comply with requirements of the JORC Code, and increased rates of mine production. However since 2003 EDR has increased as a result of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

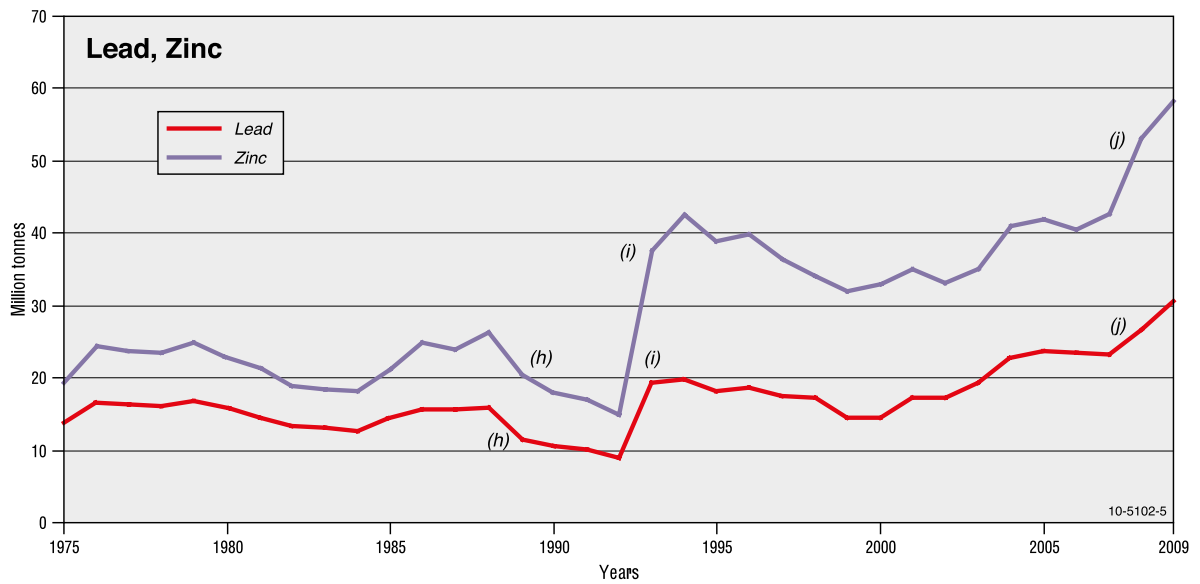
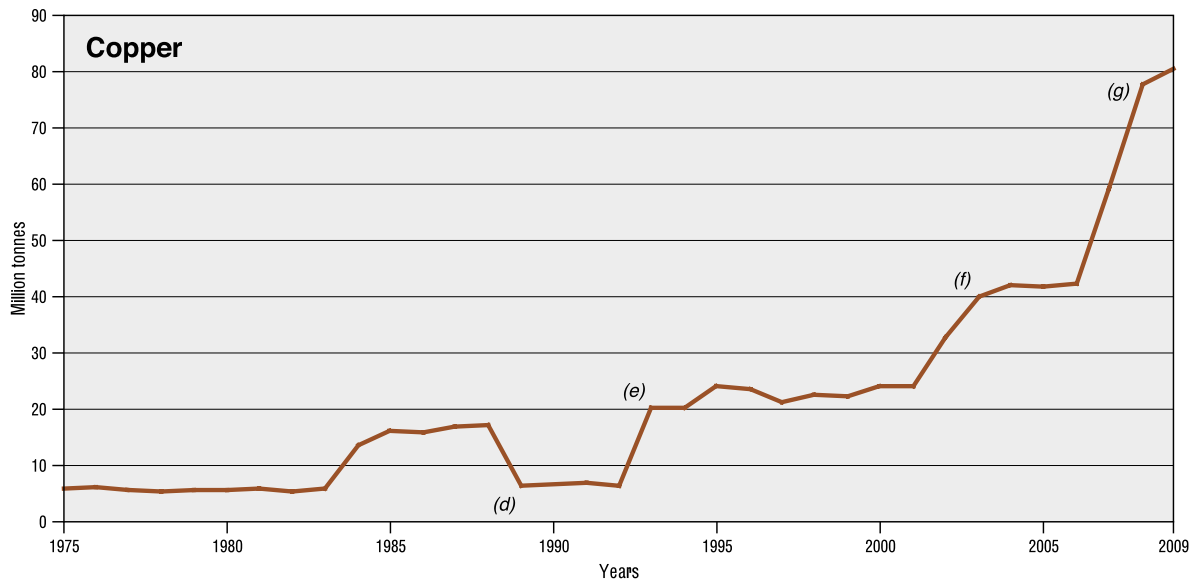
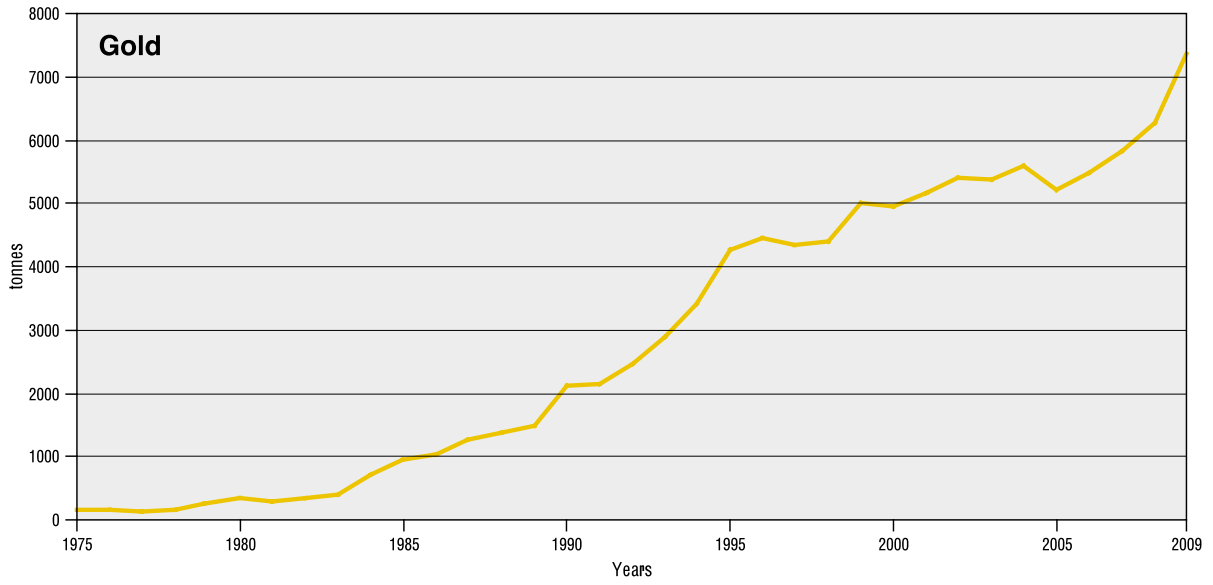
Gold

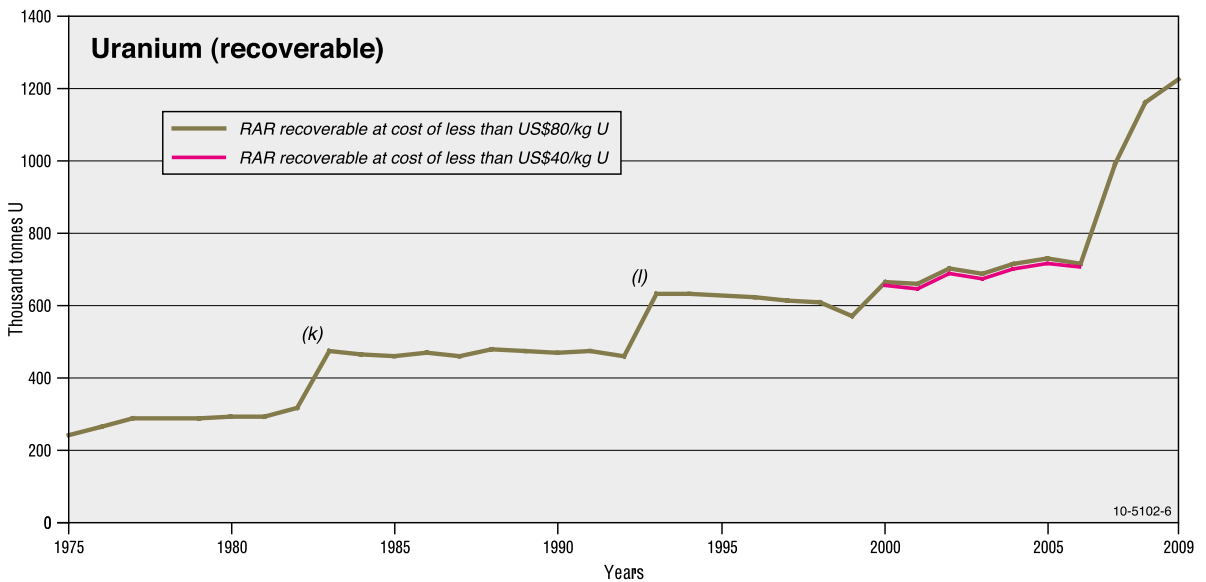
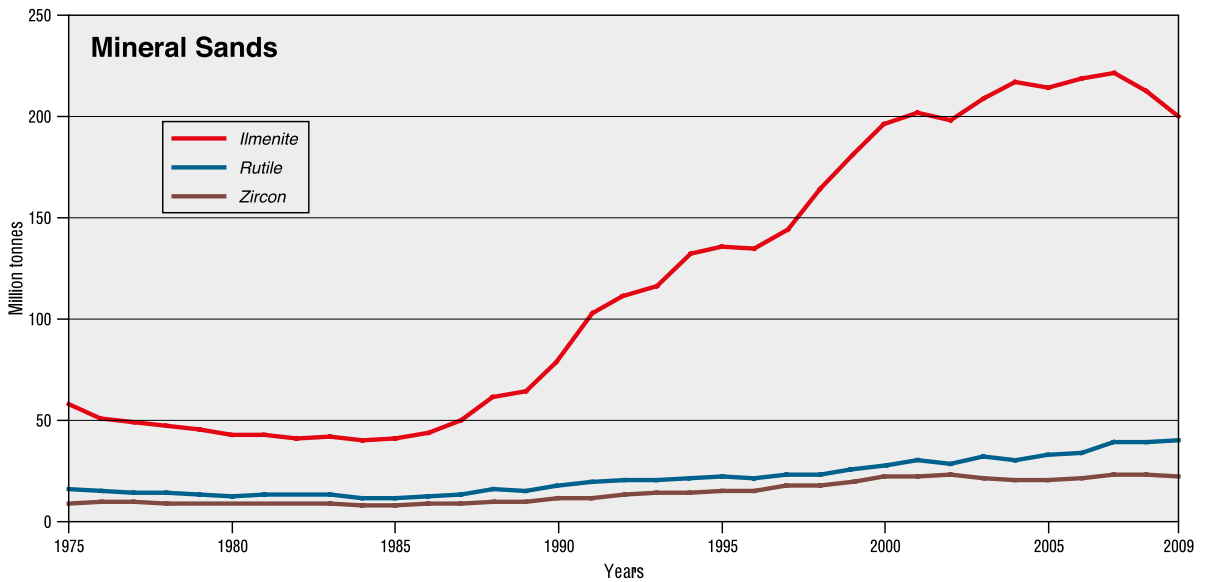
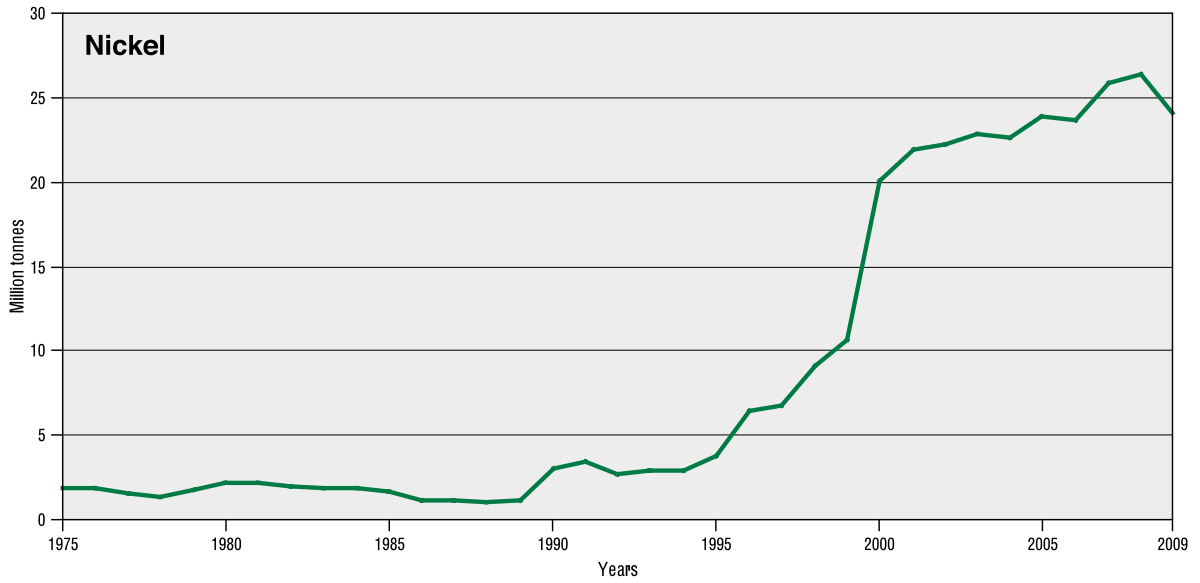
Gold EDR has increased steadily since 1975 with a clear increase in the rate of growth since 1983. Much of the increase can be attributed to the successful introduction of the carbon-based processing technology which allowed the profitable processing of relatively low grade ore deposits. In addition, the higher than previous prevailing gold prices (denominated in US\$) supported high levels of exploration for gold to the extent that gold accounted for more than half of the total mineral exploration expenditure in Australia for many years. Increased exploration contributed to the increases in EDR.

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.







Copper

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

The sharp increase in copper EDR in 1993 resulted mainly from an increase in company announced resources for the Olympic Dam deposit in South Australia (SA). Additional resources were reported also for Ernest Henry in Queensland (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 because of a large increase in resources for Olympic Dam ('g'). Drilling over recent years has outlined large resources in the southeastern 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 JORC Code, and some re-assessments of resource data for other deposits by Geoscience Australia's predecessor, the 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 to the result of re-classification of Paramarginal demonstrated resources into EDR for McArthur River in the Northern Territory (NT) and George Fisher deposits (Qld). Additional resources were reported also 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 18.2Mt. This resulted mainly because of progressive increases in resources of **lateritic deposits** at Bulong, Cawse, Murrin Murrin, Mount 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 Mount 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, Savannah, Maggie Hays, Anomaly 1, Honeymoon Well, deposits in the Forrestania area as well as new deposits at Prospero and Tapinos in Western Australia (WA), Avebury in Tasmania (Tas) and remnant resources at several sulphide deposits in the Kambalda (WA) region including Otter-Juan and Lanfranchi groups of deposits.

From 2001 onwards EDR increased at a slower rate due to the absence of further discoveries of lateritic nickel deposits and as a result of increases in resources for some deposits being 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 in which include the Gingko and Snapper deposits (NSW), Douglas-Bondi and Woornack deposits in Victoria (Vic), and the Mindarie project (SA). In addition, from 1998 onwards there were progressive increases in resources at mineral sands deposits at Ambrosia-Jacinth and Cyclone in the Eucla Basin embracing parts of SA and WA, in the North Swan Coastal Plain area north of Perth, WA, and the Blackwood Plateau region in WA. The EDR of ilmenite declined after 2007 due to reclassification of resources to lower resource categories.

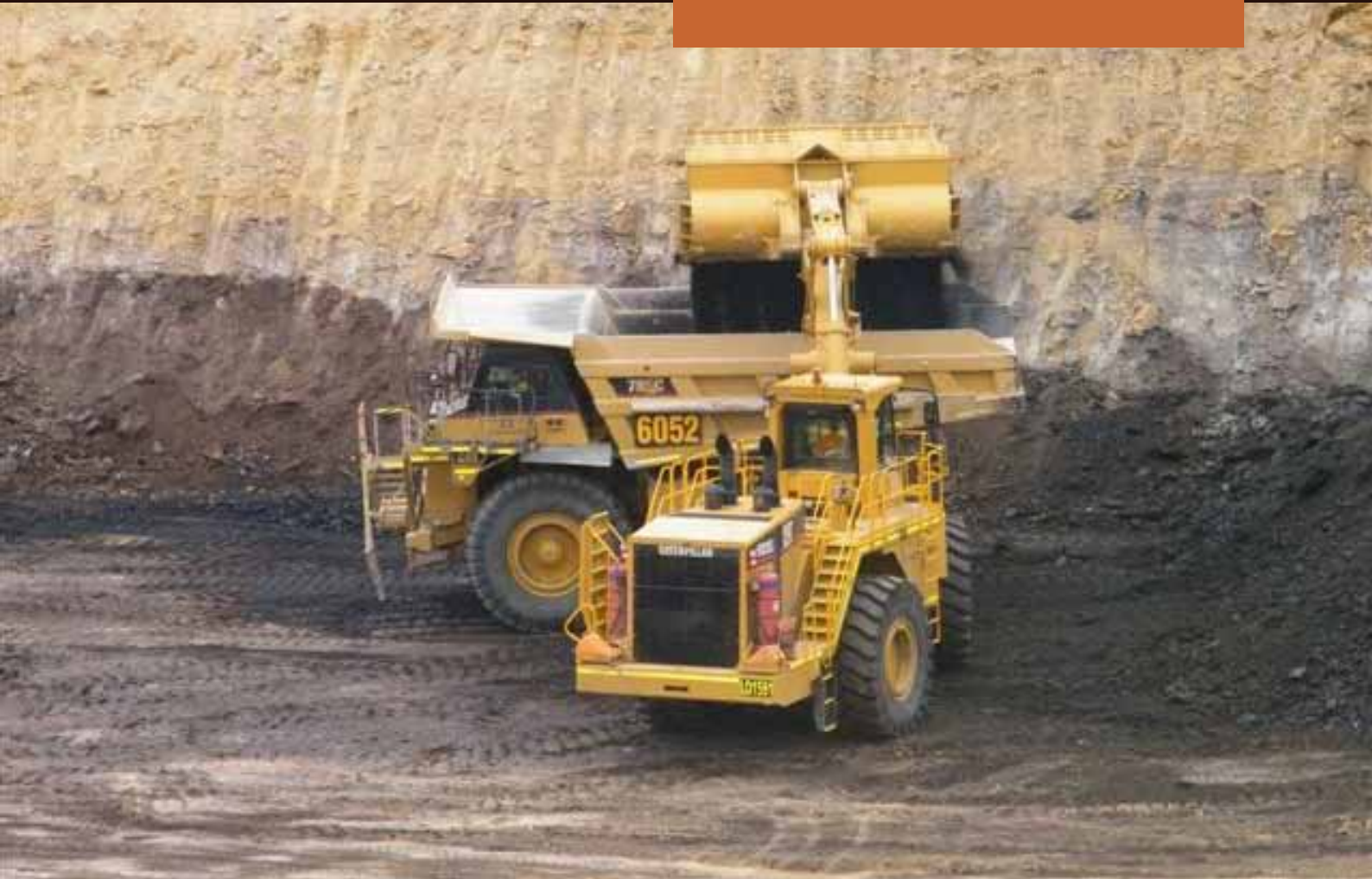
Uranium

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, (Qld) and Four Mile (SA) have Reasonably Assured Resources recoverable at less than US\$80/kg U (equates with EDR). As a result, the progressive increases in Australia's EDR for uranium from 1975 to the present (Fig. 1) were largely because of the 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 because:

- 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 Geoscience Australia's predecessor, the Bureau of Mineral Resources ('l')
- in 2000, increases were due to continuing additions to the Olympic Dam resources
- from 2007 to 2009 major increase in EDR for Olympic Dam. Drilling in recent years has outlined major extensions to the southeast part of the deposit.

COMMODITY REVIEWS



Loading coal at Cameby Downs mine in the Surat Basin, Queensland (Syntech Resources Pty Ltd)

Bauxite

Paul Kay (paul.kay@ga.gov.au)

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 ($\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$), boehmite ($\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$) and diaspore, which has the same composition as boehmite, but is denser and harder.

Australia is the world's largest producer of bauxite, representing 30% of global production in 2009. 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.

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 2009 remained consistent with the previous year. The net change in overall demonstrated resources was limited, with additions resulting from exploration and resource estimation drilling being offset by depletions created through mine production.

Accessible Economic Demonstrated Resources

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 Accessible Economic Demonstrated Resources (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 44% of AEDR comprises Joint Ore Reserve Committee (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 Securities 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.



Gove alumina plant, Northern Territory (RioTinto Alcan)

Production

Australia was the leading producer of bauxite and alumina globally in 2009, and the fifth largest aluminium producer. Based on Australian Bureau of Agricultural and Resource Economics and Sciences data, production totalled 65 million tonnes (Mt) of bauxite (30% of global production), 19.6Mt of alumina (25%) and 2Mt of aluminium (5%). 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. BHP Billiton has planned to add 1.1 million tonnes per annum (Mtpa) to the existing 3.5Mtpa capacity at the Worsley alumina refinery in WA's Darling Ranges by 2011. Bauxite extraction projects are under consideration on Cape York Peninsula (Qld) and the Darling Range area (WA). Bauxite Resources Limited (BRL) loaded its first shipment of bauxite for export to China, from the Bindoon (WA) project in November 2009. The company plans to run a 2Mtpa bauxite mine at Bindoon. The Wenlock River Basin on Cape York was declared a wild river in June 2010 under Qld's Wild River Legislation, leading to a review of the Pisolite Hills bauxite proposal. The Aluminium Corporation of China Limited (Chalco) announced in June 2010 that it would not proceed with the Aurukun bauxite mine and alumina refinery project on Cape York.

World Ranking

Based on United States Geological Survey (USGS) data for other countries, Australia's demonstrated bauxite resources of 6.2Gt rank second in the world after the Republic of Guinea and ahead of Vietnam, Jamaica, Brazil 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 energy intensity of the bauxite/alumina/aluminium industry is high with electricity accounting for around 30% of total operating costs for aluminium production.

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 2009, 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

Ron Sait (contact aden.mckay@ga.gov.au)

Coal is a sedimentary rock formed from vegetation which has been altered by temperature and pressure over millions of years. Black coal consists of anthracite, bituminous and sub-bituminous coals and ranges in age from 140 to 225 million years old. The higher rank black coals are mainly used as a fuel in the generation of electricity and to produce coke for the iron and steel making process. Black coal is used also in cement manufacturing, alumina refineries, paper manufacture, food processing and the manufacture of chemicals.

Black coal occurs in all States and the Northern Territory, but New South Wales (NSW) with 46% and Queensland (Qld) with 38% have the largest share of Australia total identified resources. Queensland (55%) and NSW (42%) produce the most black coal with locally significant operations at Collie in WA, Leigh Creek in South Australia (SA) and in the Fingal Valley and at Kimbolton in Tasmania (Tas). In Australia about 77% of black coal is produced from open-cut mines.

Resources

Recoverable Economic Demonstrated Resources (EDR) in 2009 increased 11.5% to 43.8 gigatonne (Gt) mainly because of significant increases at the at Blackwater, Dawson, Goonyella, Hail Creek, Peak Downs, Saraji and Wandoan in Qld and Mount Arthur, Oaklands North and Ulan in NSW. These increases offset large decreases at New Acland and Moranbah South in Qld and the Hunter Valley Complex in NSW. Queensland (58%) and NSW (38%) had the largest share of recoverable EDR in Australia. The Sydney Basin (31%), Bowen Basin (35%) and the Surat Basin (9%) contain most of the recoverable EDR in Australia.

In 2009, the recoverable Paramarginal Demonstrated Resources increased about 17% to 1.8Gt, mainly because some new underground thermal coal deposits were considered too small to be economic. The recoverable Subeconomic Demonstrated Resources remained decreased about 13% to 5.9Gt because some deposits were considered not to be in the identified category. The recoverable Inferred Resources increased 17% to 78.2Gt. Large increases in Inferred Resources occurred at Saraji East and Rolleston in Qld and at Mount Arthur, Ulan and United in NSW. Many new deposits with Inferred Resources were identified, including Galilee (Linc), Galilee (Liberty), Merivale, Sarum in Qld, Blackall and Doyles Creek in NSW.

During 2009 many new deposits were added to Australia's black coal resource base including, Alpha (Bandanna), Andrew, Bottle Tree, Davies Road, Galilee (Linc) Galilee (Liberty), Juandah, Kingaroy, Kogan, Kruger, Lauren, Merivale, Pentland (Linc), Redrock, Sarum, Sienna, Taabinga (Black Gold), Tin Hut Creek, Wandoan (Cougar) and Westgrove in Qld, Newstan Lochiel and Doyles Creek in NSW and Duchess-Paradise and Sargon in WA.

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 43.7Gt was nearly 100 years at current rates of production.

JORC Reserves

Joint Ore Reserve Committee (JORC) Code reserves are 14.2Gt or 32.5% of Accessible EDR. Included in the 14.2Gt are estimates by Geoscience Australia of reserves at some operating mines which had no reported JORC Code reserves. This constituted 1.2Gt or about 9% of JORC Code reserves. BHP Billiton, Rio Tinto and Xstrata Coal manage about 66% of JORC Code reserves in Australia. The resource life of the JORC Code reserves of 14.2Gt is 32 years.

Exploration

Data published by the Australian Bureau of Statistics (ABS) on coal indicated that exploration expenditure for 2009 totalled \$312.7 million which is an increase from \$276.3 million in 2008. Expenditure in Qld was \$223.4 million or 71.4% of the total and was \$73.7 million in NSW or 23.6% of the total. Exploration also occurred in SA, WA, Tas and Victoria (Vic). In 2009 coal exploration expenditure contributed 15.5% to the total exploration expenditure in Australia.

Production

During 2009 Australia produced 445 million tonnes (Mt) of raw coal (425Mt in 2008) which yielded 345Mt of saleable coal (328Mt in 2008). Exports of black coal during 2009 were 135.0Mt of coking coal valued at \$24.9 billion and 139.1Mt of thermal coal valued at \$14.4 billion. In 2009 the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) projected that Australia's saleable production will grow to 404Mt by 2014. Exports of coking and thermal coals are projected to increase to 162Mt and 163Mt respectively by 2014.

World ranking

Australia has 7% of the world's recoverable black coal EDR and ranks fifth behind the USA (31%), Russia (22%), China (14%) and India (8%).

Australia produced about 6% of the world's black coal in 2009 and ranked fourth after China (47%), the USA (17%) and India (8%).

Industry Developments

QUEENSLAND

Rio Tinto Coal Australia: The \$1 billion Clermont open-cut mine produced its first coal in April 2010. The 12 million tonnes per annum (Mtpa) thermal coal mine has a mine life of 17 years. The \$1.3 billion Kestrel mine extension is currently under construction and is planned to increase production from 4 to 5.7Mtpa from 2012.

BHP Billiton Mitsubishi Alliance: (BMA Coal): The \$625 million Daunia open-cut coking coal mine is expected to commence production at a rate of 4Mtpa from 2011. The proposed \$4 billion 5.5Mtpa Caval Ridge coking coal project is expected to produce the first coal in 2013. The proposed open-cut mine is located at the north end of the Peak Downs operation. The proposed Goonyella mine expansion from 16 to 24Mtpa is expected to be producing coal in 2013.

Xstrata Coal: In August 2009, Xstrata resumed coking coal production at Oaky No1 longwall mine. The Newlands Northern underground longwall mine extension is expected to start in 2012. Construction of the \$3 billion 30Mtpa Wandoan open-cut thermal coal project is expected to start in 2011 with production commencing in 2014.

Anglo Coal: The new \$210 million Moranbah North longwall was commissioned in 2009. The \$1.1 billion Grosvenor longwall project is planned to produce up to 5Mtpa of coking coal with construction commencing in 2012. Anglo Coal is planning to expand the Foxleigh mine from 3.3 to 4Mtpa.

Macarthur Coal: The Middlemount mine is expected to produce 1.8Mtpa by 2011. Construction of the Middlemount Coal Handling and Preparation Plant is expected to be completed in late 2010. The Olive Downs North mine is expected to commence after mid-2011 with coal hauled to the Moorvale wash plant.

Wesfarmers: At the Curragh mine a \$286 million expansion is planned to increase coking coal production from 6.5 to 8Mtpa from 2011.

Peabody Energy Australia: At the Wilkie Creek mine the company is planning to increase production from 2.3 to 10Mtpa. The Eaglefield Expansion Project envisages production increasing from 5 to 18Mtpa run-of-mine of hard coking coal from 2014. Peabody is proposing also to increase production at the Millennium mine from 1.4Mtpa up to 7Mtpa.

Ensham Resources: Ensham decided to extract coal beneath the central floodplain using underground methods instead of open-cut methods. The revised mine plan does not change the open-cut mines capacity of 12Mtpa. The new underground operations will produce up to 8Mtpa. Ensham is developing a two continuous miner operation which will produce 1.7Mtpa by early 2012.



Coal loading at Isaac Plains mine, Queensland (Aquila Resources)

Vale: The US\$138 million longwall at Carborough Downs commenced operation in mid-2010. The production at Isaac Plains open-cut project (Vale, Aquila Resources 50:50 joint venture) will increase from 2 to 3.6Mtpa from late 2010. The \$400 million Washpool open-cut coking project is expected to produce 1.6Mtpa over 18 years from 2012. The \$980 million Eagle Downs longwall mine is expecting start-up in 2014 at a production of up to 4.6Mtpa of hard coking coal. The proposed \$2 billion Belvedere longwall mine is expected to produce up to 7Mtpa of hard coking coal from 2014. Construction at the \$640 million Ellensfield 5.5Mtpa longwall project is expected to start in 2011.

New Hope Corporation: The \$36 million expansion of the New Acland mine from 4.2 to 4.8Mtpa was completed in early 2010. New Hope is proposing to incrementally increase production at New Acland to 10Mtpa.

Northern Energy Corporation: The \$35 million Colton open-cut coking coal project could be operating by mid-2011 at a production rate of 500 kilotonnes per annum (ktpa). The \$600 million Elimatta open-cut thermal coal project in the Surat Basin is planned to start in 2012 at a production rate of 5Mtpa over an initial 20 year mine life.

Tarong Energy: At the Meandu open-cut mine additional economically viable coal has been identified to extend the mine life beyond 2012. Development of the replacement Kunioon open-cut has been deferred.

Waratah Coal: The proposed \$5.6 billion 30Mtpa China First thermal coal project in the Galilee Basin includes four underground mines and two open-cut mines. The project, which is expected to commence in 2013, will be linked to a new coal terminal at Abbott Point by a new 490 kilometre (km) rail line.

Hancock Prospecting: The \$15 billion Alpha and Kevin's Corner thermal coal projects will each produce 30Mtpa commencing in 2013. A new 500km rail line will connect the mines to Abbot Point.

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

QCoal: The company plans to develop a number of mines including the Cows Project in late 2010, the Jax Project in 2011 and the Byerwen and Drake Projects in 2012.

NEW SOUTH WALES

BHP Billiton: In July 2009, approval was granted for the Mount Arthur coal mine to increase production of saleable thermal coal from 11.5Mtpa to 15Mtpa. The US\$260 million project, known as the MAC20 Project, is expected to commence in 2011. The Bulli Seam Project includes upgrading infrastructure at the Appin and West Cliff mines and extracting up to 10.5Mtpa of run-of-mine coal for 30 years.

Coal and Allied: (75% Rio Tinto): The company plans to extend the life of the Mount Thorley, Warkworth and Carrington West open-cut mines. At the Bengalla mine a feasibility study is investigating increasing production from 8.7 to 10.7Mtpa.

Xstrata Coal: 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 is under construction and is expected to produce up to 10.5Mtpa of thermal coal from 2012. In 2009, Xstrata sought approval for the Ulan West underground mine and construction of additional mining infrastructure. The 7Mtpa Ulan West project is expected to start thermal coal production in 2012. In early 2010 Xstrata sought approval for its \$900 million Ravensworth Operation Project, which is expected to start in 2013. The project includes establishment of the 16Mtpa Ravensworth North open-cut and the expansion of surface infrastructure for the Ravensworth underground longwall mine.

Centennial Coal: The 1.6Mtpa Airly Colliery commenced coal mining in December 2009. At the Clarence Colliery, the flexible conveyor train commenced operation in mid-2010. The export infrastructure for the Mandalong mine was completed in early-2010, including a new haul road. A prefeasibility study into the 4Mtpa Newstan Lochiel Project was completed in 2010. The project plans to use existing infrastructure at the recently closed Newstan mine.

Peabody Energy Australia: The Metropolitan Colliery near Helensburgh received approval in 2009, to spend US\$70 million to increase production from 1.5 to 2.5Mtpa, extending the mine life to more than 20 years.

Gloucester Coal: An expansion to 2.8Mtpa is scheduled for completion in 2010. Gloucester is planning to further increase production to 3.5Mtpa from 2014.

Yancoal Australia: At the Ashton mine the proposed 3.6Mtpa South East Open-Cut (SEOC) is planned to replace the existing open-cut mine. The 6Mtpa Stage 1 Moolarben open-cut mine commenced in late 2009. The Stage 2 Moolarben underground mine is expected to commence in 2012. Yancoal received approval in late 2009 for the \$80 million Stage 3 Austar Longwall Top Coal Caving (LTCC) mine extension project to extract 3.6Mtpa of coal in an area east of the current operation starting in 2012.

Gujarat NRE Coking Coal Ltd: At NRE No1 Colliery the company plans to increase production to 3Mtpa by installing a longwall in 2012. In September 2009 longwall mining commenced at the NRE Wongawilli Colliery at a rate of 1.4Mtpa with a plan to raise production to 3Mtpa in 2015.

Idemitsu Australia Resources: The company is planning a \$150 million expansion of the Boggabri open-cut mine to triple coal production to more than 4Mtpa by 2013.

Whitehaven Coal Ltd: The Narrabri Longwall Project Stage 1 surface construction was completed in mid-2010. Stage 2 includes a 6Mtpa longwall which is expected to be delivered in late 2010 with start-up in mid-2011. Whitehaven is expanding the Werris Creek, Tarrawonga, Rocglen and Sunnyside open-cut mines to produce a total of 5.5Mtpa of saleable coal by September 2010.

Wyong Areas Coal Joint Venture: (Kores Australia 82.25%): The \$700 million Wallarah 2 Coal Project is planned to produce 4 to 5Mtpa of export quality thermal with construction expected to commence in late 2010.

Coalworks Ltd: At the Oaklands North Project near Jerilderie an open-cut thermal coal mine is planned to produce export thermal coal. Coalworks is investigating the possibility also of developing a coal-to-liquids plant and/or a power station.

WESTERN AUSTRALIA

Aviva Corporation Ltd: The proposed \$1 billion 400 megawatt (MW) Coolimba Power Station will use 2.4Mtpa of coal from the Central West.

The Griffin Group: Mining commenced at the \$20 million Ewington 1 open-cut mine near Collie in April 2009 with a production of 3.4Mtpa.

Perdaman Chemicals and Fertilisers: Perdaman plans to construct a \$3.5 billion fertiliser plant at Collie using 2.7Mtpa of coal and gasification technology. The project is planned to produce 2.0Mtpa of urea starting from 2013.

Rey Resources: At the Duchess-Paradise Project in the Canning Basin, Rey Resources is planning to develop a \$130 million trench highwall mining operation. About 2.5Mtpa of thermal coal is planned to be trucked 180km to the Port of Derby for export.

SOUTH AUSTRALIA

Alinta Energy: At the Leigh Creek mine, Alinta is investigating the feasibility of extending the life of the open-cut beyond 2018.

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

Brown Coal

Ron Sait (contact aden.mckay@ga.gov.au)

Brown coal, also called lignite, is a low rank high moisture content coal which is used mainly to generate electricity. In Australia brown coal occurs in all States and is Tertiary in age (15 to 50 million years old). The Gippsland Basin in Victoria contains a substantial world class deposit of brown coal where seams can be up to 330 metres thick. In Australia brown coal is mined only in Victoria where the open-cut mines of Anglesea, Loy Yang, Yallourn and Hazelwood supply coal to nearby power stations. Brown coal is mined also at Maddingley to produce a fertiliser product. Energy Brix Australia produces briquettes for industrial and domestic heating and Australian Char Pty Ltd produces low ash and low sulphur char products.

Resources

Recoverable Economic Demonstrated Resources (EDR) for 2009 was 37.1 gigatonne (Gt) which was slightly less than in 2008 as a result of production losses. Recoverable Paramarginal Demonstrated Resources increased by about 1% to 39.1Gt because of a reassessment by Spitfire Oil of the Salmon Gums deposit in Western Australia (WA). Subeconomic Demonstrated Resources remained unchanged at 16.3Gt. Recoverable Inferred Resources increased about 0.1% to 101.2Gt following the reassessment at the Salmon Gums 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 87% 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, both in Victoria (Vic). The resource life of the accessible EDR of 32.1Gt is about 490 years.

JORC Reserves

No brown coal resources are Joint Ore Reserve Committee (JORC) Code compliant. However, Geoscience Australia estimated reserves at the operating mines from published information to be about 4.7Gt. 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 2008–09 was 68.3 million tonnes (Mt) valued at \$2.3 billion, all from Vic. 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 ahead of the USA (20%) and China (12%). Australia produces about 7% of the world's brown coal and is ranked as the fifth largest producer after Germany (21%), Russia (10%), Turkey (9%), USA (8%), China (7%) and Greece (7%).

Industry Developments

Environmental Clean Technologies Ltd: A Stage 1 \$440 million 2 million tonnes per annum (Mtpa) Coldry plant is planned to be established near the Loy Yang mine in Vic with exports commencing in 2014. 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 pilot plant is planned to be established to assess the suitability of MBD Energy's carbon dioxide (CO₂) biosequestration process which uses algae to capture flue gases. The MBD Energy process produces oil-rich micro algae suitable for the production of plastics or fuel and a stock feed.

HRL Ltd: In September 2009 HRL announced that a \$750 million power station is proposed to be located at Morwell in the Latrobe Valley, Vic. The Dual Gas Demonstration Project will generate up to 550 megawatts (MW) of electricity using syngas and natural gas. The project is planned to commence in 2013 to demonstrate the HRL integrated drying gasification combined cycle (IDGCC) technology at a commercial scale

International Power plc: In July 2009, a \$10 million carbon capture plant began operating at the Hazelwood Power Station in the Latrobe Valley, Vic. The plant will capture about 9000 tonnes per annum (tpa) of CO₂, which reacts with ash water to produce an inert and commercially usable product, calcium carbonate.

Exergen Pty Ltd: Exergen has developed a process called Continuous Hydrothermal Dewatering (CHTD) which reduces the water content of brown coal. By 2014 Exergen plan to mine, dry and export coal from a \$1.5 billion 12Mtpa processing plant located in the Latrobe Valley, Vic.

Ignite Energy Resources: Ignite Resources has developed a Super Critical Water (SCW) reactor which converts brown coal into oil and coal products. In July 2009, Ignite Resources and TRUenergy agreed to develop a SCW reactor demonstration plant at the Yallourn mine, Vic. The plant is expected to commence in 2010.

Latrobe Fertiliser Pty Ltd: A \$2 billion coal-to-urea plant is planned to be developed in the Latrobe Valley, Vic. The plant will use proven technology to produce 1.2Mtpa of urea fertiliser from 2013.

CO₂CRC: In 2009 a post combustion CO₂ capture research facility was commissioned at the Hazelwood Power Station in Vic. The CO₂CRC H3 capture projects will trial three CO₂ capture technologies including solvents, membranes and absorbents.

Victorian Government: In August 2009, the Victorian Government announced \$16 million in funding for new clean coal research and the establishment of a new organisation called Brown Coal Innovation Australia (BCIA). The initiative would provide opportunities to develop low emission brown coal technology. The government organisation Clean Coal Victoria will plan for the long term extraction, development, use and rehabilitation of Victoria's coal resources.

Brown Coal-to-Liquids projects include Blackham Resources at Scaddan and Spitfire Oil at Salmon Gums in WA, Hybrid Energy Australia at Kingston and Syngas Ltd at Clinton in South Australia and Regal Resources at Oak Park in Vic.

Coal Seam Gas

Ron Sait (contact aden.mckay@ga.gov.au)

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

CSG 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 generate electricity. Water is produced as a by-product of CSG production, although any beneficial reuse of the water depends on a number of factors including its quality, the cost of treatment and required pipeline infrastructure. Water of suitable quality can be used for town water, aquaculture, recharging aquifers, wetlands and recreational lakes or at mining operations and power stations. Poor quality water may be required to be contained in storage ponds.

Resources

In December 2009, the proven and probable (reported as '2P' under the Society of Petroleum Engineers—Petroleum Resources Management System <http://www.spe.org/industry/reserves/prms.php>) reserves of CSG in Australia were 26 132 Petajoules (PJ) a 61.5% increase over the 2008 2P reserves of 16 179 PJ. The life of the resource is more than 130 years at the current annual rate of extraction of 195 PJ. Queensland has 23 038 PJ (or 88.1%) of the 2P reserves with the remaining 3094 PJ in New South Wales. Queensland's Surat Basin has 64.9% and the Bowen Basin has 23.2% of Australia's 2P CSG reserves respectively. Note that there are no CMM reserves.

Exploration expenditure

Data relating to exploration expenditure are not published by the Australian Bureau of Statistics (ABS) on either a State or Australia-wide basis.

Production

In 2009, CSG production was 195 PJ, which is a 41% increase on the 2008 production of 138.5 PJ. Queensland produced 189 PJ (or 97%) from the Bowen Basin (117 PJ) and Surat Basin (72 PJ). In New South Wales, 5.8 PJ was produced from the Sydney Basin (5.6 PJ) and Gunnedah Basin (0.2 PJ). Note that CMM is not counted in CSG production statistics.

Industry Developments

QUEENSLAND.

Shell Australia: The company is investigating the development of a liquefied natural gas (LNG) plant at Curtis Island near Gladstone. The plant is expected to produce up to 16 million tonnes per annum (Mtpa) of LNG from 2015. Shell has acquired 30% of Arrow Energy's CSG resources.

Arrow Energy: The Stratheden project located in the Surat Basin, 20km northwest of Dalby commenced producing CSG in July 2009. The Arrow Energy and ERM Power Braemar 2 \$545 million 450 megawatt (MW) open cycle CSG fired power station was completed in June 2009. The 540MW Braemar 3 open cycle CSG fired power station is planned to be in operation from 2012. Arrow Energy is planning to develop a CSG to LNG project at Fisherman's Landing in Gladstone. The project is expected to produce up to 3Mtpa of LNG from late 2012 for a period of 12 years. The proposed Surat Gas Project involves the staged development of approximately 1500 production wells and infrastructure in an area around Arrow's existing Surat fields.

Australia Pacific LNG (APLNG): In October 2009, Origin Energy and ConocoPhillips formed a 50:50 joint venture called Australia Pacific LNG. The joint venture plans to develop four LNG plants at Laird Point on Curtis Island near Gladstone. The first train is expected to be commissioned in late 2014. With all plants operational by 2020 the project will produce 14 to 16Mtpa of LNG. Stage 1 of the Talinga CSG Project near Chinchilla was commissioned in November 2009. In January 2010, commissioning commenced on Stage 2 of the Talinga Project and in December 2009, Origin Energy commissioned the Darling Downs 630MW CSG fuelled power station.

Santos Ltd: The \$7 billion Gladstone LNG Project (60% Santos/40% Petronas) is a 3 to 4Mtpa LNG plant which is planned to commence exports in 2014. CSG is planned to be sourced from Santos' CSG fields in the Bowen and Surat Basins.

Queensland Gas Company (a Division of BG Group): The CSG fuelled 135MW Condamine Power Station was commissioned in late 2009. The \$8 billion Queensland Curtis LNG Project involves transporting CSG via a 340km pipeline to Gladstone where the gas is converted into LNG on Curtis Island. Construction of the 12Mtpa project is planned to commence in 2010 with commissioning in 2013. In March 2010, the company and BOC Ltd signed a \$100 million agreement which will result in the construction of a LNG plant next to the Condamine Power Station. The plant will produce LNG to fuel trucks. Construction is expected to start in early 2011.

Pacific GTL Ltd: The \$1.5 billion SunState GTL Project is planned to produce 6 million barrels per annum of liquid fuels. Construction of the CSG to liquids project is expected to commence in 2010 at a site east of Miles.

Molopo Australia: Molopo plans to construct a \$65 million 60MW power station in Moura fuelled by CSG from the Mungi field. Molopo is investigating a 100MW CSG fuelled power station on the Harcourt South field also located near Moura.

Bow Energy: The 30MW CSG fired power station located at Blackwater is expected to be commissioned in early 2011.

NEW SOUTH WALES

Coal and Allied Ltd: At the Mount Thorley Warkworth in the Hunter Valley a \$5.5 million pilot project is aimed at reducing fugitive emissions of methane released during mining.

Metgasco Ltd: The Richmond Valley 30MW CSG fired power station is planned to provide electricity to northeast New South Wales. Metgasco plans to provide CSG to southeast Qld via the 145km long Lions Way pipeline.

AGL: The northern expansion of the Camden Gas Project includes the proposed establishment of a gas extraction plant at Varroville.

Eastern Star Gas (ESG): The Wilga Park gas fired power station is being expanded to 40MW. The first new 3MW generator was commissioned in July 2009. Gas for the power station is primarily sourced from the company's Narrabri Coal Seam Gas Project.

Macquarie Generation: Seventy-five kilometres of pipelines are planned to supply mine methane gas from local underground coal mines to the Liddell Power Station in the Hunter Valley.

Coal to Liquids

Ron Sait (contact aden.mckay@ga.gov.au)

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, naphtha, tars, alcohols and methanol. There has been extensive research into converting coal to a liquid, for which there are basically 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 in Victoria produced gas for the Melbourne market using briquettes made from 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.

Underground Coal Gasification (UCG) Synthetic gas (syngas), can be produced by underground, or in-situ coal gasification. In this method, fuel gases are produced underground when a coal seam gets enough 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 the USA, Canada, South Africa, India, Vietnam, Australia, New Zealand and China to produce electricity, liquid fuels and syngas.

Resources

In Australia in 2009, no CTL projects were considered economic given that there are only two operating projects in the world and all those in Australia are in the demonstration phase of development. Since CTL technology is well established, the CTL resource of 16 300 million barrels is considered to be Paramarginal Demonstrated Resources. The resources from operating mines were not included except at New Acland where the New Hope Corporation plans to develop CTL alongside the 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 locations of coal which has been considered suitable and available for CTL conversion include the Surat, Clarence-Moreton, Oaklands and Gippsland Basins.

Industry Developments

Altona Energy plc: The Arckaringa Project requires a 10 million tonnes per annum (Mtpa) open-cut mine at the Wintinna coal deposit in South Australia (SA). The coal is feedstock for a 10 million barrels per annum CTL plant and a 560 megawatts (MW) cogeneration power plant.

New Hope Corporation: A one tonne per hour CTL concept test plant is planned to be located at the Jeebropilly mine in Queensland (Qld). The test plant will enable the design of a 25 tonne per hour pilot plant.

Ambre Energy Ltd: At the Felton coal deposit in Qld a 150 000 tonnes per annum (tpa) Di-Methyl Ether (DME) pilot plant is planned to demonstrate coal gasification technology. If successful, Ambre proposes expanding the plant to process 3.8Mtpa of open-cut coal to produce 800 kilotonnes per annum (ktpa) of DME and 200MW of electricity.

Coalworks Ltd: A CTL plant producing 2.5 million barrels of petrol per annum is being investigated at the Oaklands coal deposit in New South Wales.

Spitfire Oil Ltd: A 3.5Mtpa open-cut mine at Salmon Gums in Western Australia (WA) 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.

Blackham Resources: Based on current resources a coal-to-liquids project at the Scaddan brown coal deposit in WA could produce up to 14 million barrels per year. In November 2009 Blackman signed an agreement with Synfuels China to develop a coal-to-liquids Fischer-Tropsch facility.

Hybrid Energy Australia: The proposed coal-to-liquids FuturGas Project at the Kingston brown coal deposit in SA is planned to produce 3.7 million barrels of synthetic fuel per annum and 40MW of low emission electricity.

Syngas Ltd: A production of 5.7 million barrels of fuel per year is planned to be produced from a coal-to-liquids project at the Clinton brown coal deposit in SA.

Underground Coal Gasification (UCG)

Linc Energy: UCG Generator 3 was decommissioned in late 2009 and UCG Generator 4 was started in February 2010. In April 2009, the demonstration gas to liquids (GTL) plant at the Chinchilla UCG project was officially opened. In late 2009 the GTL plant was modified and recommissioned in early 2010.

Carbon Energy: In January 2009 trial syngas production commenced at the Bloodwood Creek UCG Project. In July 2009 construction commenced on a 5MW syngas fuelled power plant with commissioning expected in late 2010. An additional 20MW Phase 2 power plant incorporating carbon capture and storage technology is planned.

Cougar Energy: Construction of the Kingaroy UCG trial project began in September 2009 and in March 2010 the coal seam was successfully ignited and syngas production commenced. If the trial is successful Cougar plans to build a 186MW syngas fuelled power plant with plans to expand to a 400MW plant.

Companies with less advanced UCG projects include Black Gold Resources, MetroCoal Ltd, Liberty Resources, Regal Resources, Central Petroleum and Eneabba Gas.

Copper

Keith Porritt (keith.porritt@ga.gov.au)

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 Cadia-Ridgeway, Northparkes and Tritton in New South Wales (NSW), Ernest Henry and Osborne (Qld), Nifty, Telfer 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 more than 20 kilograms (kg) of copper and suburban homes have around 200kg of copper.

Resources

Australia's total demonstrated resources of copper rose by 5 million tonnes (Mt) in 2009 to 124Mt. The increase occurred mostly in SA and NSW.

Australia's Economic Demonstrated Resources (EDR) of copper rose by 2.5Mt to 80.4Mt, an increase of 3% on the EDR in 2008. South Australia has the largest EDR at 56.5Mt which is 70% of the national total. Almost all of the SA EDR are associated with the Olympic Dam deposit, where EDR of 54.6Mt is relatively unchanged from 2008 after two years of significant increases. NSW rose from 9% to rank second in 2009 with a 12% share of the national total EDR as a result of increased resources at Cadia East and other central NSW deposits. The balance of Australia's copper EDR is largely in Qld with 11% and WA with 5%.

Inferred Resources rose by 12% to 38.4Mt in 2009 largely as a result of increased Inferred Resources at Olympic Dam. South Australia holds 66% of Australia's Inferred Resources (mostly at Olympic Dam) followed by Qld 18%, WA 10% and NSW 4%.

Accessible EDR

All copper EDR is accessible.

JORC Reserves

Joint Ore Reserve Committee (JORC) Code reserves account for around 29% 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 91 years, but using the ore reserve and dividing by annual production gives a resource life of only 26 years.

Exploration

Spending on exploration for copper fell by 54% in 2009 to \$135 million. Expenditure in Qld of \$50 million was 37% of all copper exploration. Expenditure in SA of \$35 million represented a further 26%. 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 22% of spending on copper exploration across a range of projects largely focused on seeking volcanogenic massive sulphide ore deposits such as DeGrussa. NSW had 8%, with the remainder in the Northern Territory (NT) with 4%, Victoria with 2% and minor copper exploration in Tas. Expenditure on exploration for copper made up 7% of all mineral exploration.

Production

In 2009, Australia's mine production of copper totalled 853 kilotonne (kt) of contained copper, 4% lower than 2008 (887kt). Queensland continued to dominate production with 267kt, largely from the Mount Isa region.

This was 31% less than in 2008 and represented 31% of Australian production, significantly down from 44% in 2008, largely as a result of lower production at Ernest Henry. South Australia held the second largest producer position with an increase of 28% to 252kt. Olympic Dam and the newly commissioned Prominent Hill mine produced SA's output, contributing 18% and 11% respectively of national production. New South Wales produced 161kt (19%) in 2009, 11% more than in 2008, largely from Cadia-Ridgeway, Northparkes and Tritton. Western Australia produced 145kt (17%), up 15%, mainly from Nifty, Telfer and Golden Grove. Tasmania produced 27kt, down 1% with almost all coming from Mount Lyell.

The value of Australia's exports of copper concentrates and refined copper in 2009 totalled just over \$5.8 billion, down 13% on the \$6.7 billion in 2008 but holding at just under 3% of the value of total merchandise exports. Australian dollar copper prices decreased for a third year in 2009 after substantial rises in the three years prior to 2007. The average copper price was down 20% in 2009 to \$6398 a tonne compared to the average of \$7975 a tonne in 2008. However, the average copper price in the December quarter of 2009 was \$7287, which was 11% higher than in the corresponding quarter of 2008. Copper exports in 2009 decreased 3% to 787kt reflecting the 4% decrease in copper production.

World Ranking

Based on United States Geological Survey (USGS) data for other countries, Australia has the second largest world economic resources of copper (13%) after Chile (27%) and ahead of Peru (11%), Mexico and the USA with 6% each, and Indonesia and China with 5% each. As a producer, Australia ranks sixth in the world, with 5% of world copper production, after Chile (34%), Peru and the USA (both 8%) and China and Indonesia (both 6%).

Industry Developments

Olympic Dam (SA): BHP Billiton reported that 156kt of copper cathode was produced during 2009. This was 21% less than in 2008 and 34% below the nameplate capacity of 235 kilotonne per annum (ktpa). Production, which was being impacted already by maintenance activities, was greatly reduced after 6 October 2009 when a falling ore skip caused extensive damage to the Clark Shaft haulage system as the result of mechanical failure. Ore hoisting continued at 25% of capacity from the secondary Whenan Shaft. Planned maintenance activities were brought forward during the repair period and the mine returned to full production during the June quarter 2010.

In 2008, BHP Billiton completed a two-year pre-feasibility study to examine capacity expansion options. Based on this work, a project configuration was described in a draft Environmental Impact Statement (EIS) provided to the Australian, SA and NT governments. The EIS was released for public comment on 1 May 2009. 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 increase ore production six-fold. The project would increase copper production to 750ktpa, 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 350ktpa 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. The proposed expansion would be a progressive development, requiring construction activity over a period of 11 years. The Supplementary EIS (response document) is being prepared and is planned for submission to relevant governments in late 2010. Following completion of the approvals process, BHP Billiton will undertake the required feasibility studies and its Board will decide on the final investment case.

Mount Isa and Ernest Henry (Qld): Copper-in-concentrate production in 2009 from Xstrata Plc's Mount Isa and Ernest Henry operations totalled 198kt, a decrease of 25% on 2008. At the Mount Isa operations, increased mill throughput and higher-grade stopes led to a 7% rise in production to 162kt. However, at Ernest Henry production decreased 68% to 36kt because of the impact of planned lower grades, record wet season flooding (which required extensive pit dewatering and the use of lower-grade stockpiles in the first half) and the higher rate of stripping required to access the next ore zone. The Mount Isa smelter produced 214kt of anode, a decrease of 9% over 2008 as a result of lower feed from Ernest Henry. The Townsville refinery produced a record 277kt of copper cathode, an increase of 4% on 2008, from Mount Isa smelter anode plus some anode from Xstrata's Altonorte smelter in Chile.

At the Mount Isa underground copper operations a scoping study into a 'starter pit' to produce 20ktpa of copper concluded it is potentially viable and a pre-feasibility study will be completed in 2010. A second pre-feasibility

study commenced into the potential for underground mass mining of low-grade remnant and halo mineralised zones in the 1100 orebody at the X41 Mine. Exploration drilling has been focused on the Western 1100 orebody and the 500 orebody in the X41 Mine and on the Southern 3500 orebody in the Enterprise mine. Drilling in 2010 will target extensions to the Western 1100 orebody and the 500 orebody.

At Ernest Henry a feasibility study to convert the open pit operation into a large-scale underground sub-level cave mine was completed in 2009 and the development was approved by the Xstrata Board in December 2009. The project will extend the life of Ernest Henry's operation by at least 12 years to 2024 and produce an average of 50ktpa of copper with gold and magnetite credits. Decline development continued during the second half of 2009, reaching a total of 2928 metres (m) on 31 December 2009. Current regional exploration drilling is focused on targets in the Cloncurry and Mount Isa regions which have the potential to provide additional ore feed to the Ernest Henry and Mount Isa plants.

Prominent Hill (SA): Located in central SA and built during 2007 and 2008, this new operation comprises an open pit, grinding and flotation plant, a village to accommodate more than 1000 people, an airstrip and a borefield. Production from the plant commenced in February 2009 and commissioning was completed on 30 April 2009 to be followed by a successful ramp-up delivering a total production for 2009 of 96kt of copper and 75 535 ounces (oz) of gold contained in concentrate. The high average grade of this concentrate of 54% copper is attractive to smelters for blending with lower grade concentrates to improve feed grades. OZ Minerals Limited forecasts annual production to average 100 to 110ktpa of copper and 80 000 to 90 000oz of gold for 2010 to 2012. Feasibility studies for an underground mine to augment production from the open-pit included 23 500m of infill drilling on the Western Copper deposit aimed at upgrading the Inferred Resources and testing for extensions to the east, west and at depth. Subsequently the development of the underground mine was approved mid 2010. Step-out drilling close to the open pit is also underway and is aimed at extending this resource at depth and along strike to the west and east. OZ Minerals plans to spend \$20 million on Prominent Hill regional exploration in 2010 including a joint venture on neighbouring leases held by IMX Resources Limited.

Cadia-Ridgeway (NSW): During 2009 Newcrest Mining Limited reported a further significant increase in the Cadia Province Mineral Resource to 44 million ounces (Moz) of gold and 8Mt copper in 3 gigatonne (Gt) of ore. Most is at Cadia East which now has a total resource of 2.3Gt at 0.44 grams per tonne (g/t) of gold and 0.28% copper after an increase in 2009 of 5Moz of gold and 1Mt of copper. Copper production was 29kt for Cadia and 27kt for Ridgeway for the 12 months to 30 June 2009.

Development of the \$500 million Ridgeway Deeps block cave mine continued on schedule with the first ore introduced to the crusher in June 2009, two years after project commencement. Expenditure in the 2008/09 financial year was \$250 million. Production from Ridgeway Deeps was increased to progressively replace the almost exhausted Ridgeway sublevel cave mine. Drilling confirmed reserves in a second caving block below the current Ridgeway Deeps block cave.

The Cadia East project is evaluating the potential for a large scale panel caving operation with an expected life of more than 30 years. The pre-feasibility study has proceeded to the feasibility phase and expenditure for the 2008/09 financial year was \$115 million. Drilling and data analysis continued in 2009 and a second option was developed which would access the higher-grade ore at the base of the known resource. Under the initial option the panel cave would commence in the upper levels of the orebody. Newcrest has reported that Cadia East's panel cave will be Australia's largest underground mine. The anticipated capital expenditure is almost \$2 billion with first production expected in the second half of 2012.

Northparkes (NSW): Production for 2009 was 34kt of contained copper, which was up 38% from the 25kt in 2008 but lower than the 43kt in 2007 and 83kt in 2006. The E48 block cave project was restarted in October 2009 after being approved in 2006 but deferred in response to economic conditions when 75% complete at the end of 2008. The resumed project is expected to cost US\$160 million and extend the mine's life to 2023. Underground production was largely sourced from the E26 Lift 2 North block cave, with production from the E48 block cave project in the last quarter. Open cut production was used to maintain full mill capacity.

Golden Grove (WA): Production for 2009 was 31kt of copper in concentrate. Minerals and Metals Group (MMG) will spend \$US24 million on a new tailings storage facility to handle another 15 years of tailings from the copper and zinc mine, reflecting recent exploration success. MMG, an unlisted Chinese Government company, acquired

the Golden Grove, Rosebery (Tas) and Century (Qld) base metal mines from OZ Minerals on 16 June 2009 as part of a solution to OZ Minerals refinancing issues resulting from low commodity prices and high levels of capital expenditure in 2008.

Lady Annie, Leichhardt, Eloise and Mount Gordon (Qld): During 2009, several copper mines were on care and maintenance following low copper prices in 2008 and a north Qld high rainfall event in February 2009. These mines included Lady Annie, Leichhardt (Mount Watson), Eloise, Mount Gordon and Nifty Oxide. Two were acquired by Cape Lambert Resources during 2009 from the receivers of companies under liquidation, namely Lady Annie from CopperCo Limited and Leichhardt from Matrix Metals Limited. Lady Annie was subsequently on-sold to China Sci-Tech Holdings Limited for \$135 million after the withdrawal because of poor market conditions of an initial public offering of the project into a new company called Q Copper.

Diamond

Keith Porritt (keith.porritt@ga.gov.au)

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 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 but only a very small proportion has 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) increased by 14% in 2009 for both gem/near gem and industrial to 104.8 million carats (Mc) and 109.1Mc respectively. This increase is associated with the Argyle mine in Western Australia (WA) where transition work from open pit to underground operations continues.

Accessible EDR

All diamond EDR is accessible for mining.

JORC Reserves

The Joint Ore Reserve Committee (JORC) Code reserves account for 82% of 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 indicates that expenditure on exploration for diamond in Australia in 2009 was \$8 million, down 55% on 2008.

Production

Australia produced 10.8Mc of diamond in 2009, 4.9Mc less than in 2008 and about one third of what has been produced during many previous years. Production was almost entirely from Rio Tinto's Argyle mine, which produced 10.6Mc. Production was scaled back in 2009 as demand for rough diamonds, which is highly reliant on the US economy, was severely affected by the world financial crisis. Argyle production is mostly industrial and cheap diamonds, but includes high value rare pink diamonds. Future production is expected to be about 60% of Argyle's historical annual average of 34Mc 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 is 18% of current world economic resources and ranks third behind the Democratic Republic of the Congo (Kinshasa) with 25% and Botswana with 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 sixth largest producer of diamond by weight after Botswana, Russia, Congo, South Africa and Canada. The ranking is similar for gem/near gem diamond with Australia the sixth largest producer after Botswana, Russia, Canada, Angola and Congo. For industrial grade diamond, Australia is the fifth largest producer after Congo, Russia, South Africa and Botswana.

Industry Developments

Argyle (WA): In 2009, Rio Tinto slowed the \$1.86 billion transition of its open cut Argyle mine to an underground operation because of the deterioration in global markets, going ahead with only critical development activities. Production also was scaled back with a three month suspension from March and employment reduced from 360 to 140 at the Kimberly based operation. Diamond production for 2009 was 10.6Mc compared to 15Mc in 2008. Argyle production includes rare pink diamonds. The block cave underground mine is expected to commence production in 2012, which compares with an estimate in October 2008 that it would begin production in mid to late 2010. In October 2008 development was one third complete at a cost of \$670 million. Production from Argyle's open pit mine is expected to continue through to 2012. The underground development is expected to produce 20–25Mc a year for seven years, extending the mine life to 2018.

Ellendale (WA): GEM Diamonds Limited focused on the high revenue per tonne E9 pipe and placed its E4 pipe and E4 satellite pipe on care and maintenance in February 2009, resulting in reductions in staff and overheads. Life of the mine is 3.5 years at current production rates at E9. In 2009, 4.1 million tonnes (Mt) of ore was treated to recover 0.2Mc of rough diamonds compared to 8.3Mt yielding 0.6Mc in 2008. An average 2009 price of US\$232/carats was achieved, compared to US\$185/carats in 2008 and US\$137/carats in 2007. Fancy yellow diamonds accounted for 7% of diamonds sold in 2009, with an average price of US\$2480/carats.

Merlin (NT): North Australian Diamond's Merlin project consists of 14 kimberlite pipes, nine of which were open-pit mined from 1998 to 2003 under the ownership of Rio Tinto. Operations in 2009 focused on resource definition drilling and pre-feasibility production trials with diamonds to be valued when a sufficiently large parcel is recovered. A 2008 revaluation of Merlin diamonds indicated an approximate price of US\$200/carats. A February 2010 resource estimate increased Merlin Indicated and Inferred Resources by 2Mc to 6.2Mc.

Gold

Mike Huleatt (mike.huleatt@ga.gov.au and alan.whitaker@ga.gov.au)

Strong gold prices continued throughout 2009. The impact of the global financial crisis resulted in a sharp fall in exploration expenditure in the first half of the year which a strong second half could not offset resulting in an overall reduction in spending for the year. However, exploration continued to generate a very large number of intersections of economic significance justifying further work. In contrast, production rose in 2009 after a sharp fall in 2008, but still remained beneath the 2007 level.

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

Resources

Australia's gold resources occur and are mined in all States and the Northern Territory (NT). At the end of 2009, total Australian gold resources were 993 tonnes higher than at the end of 2008. After allowing for the replacement of those resources lost to production (223 tonnes) newly delineated resources added to the national inventory totalled 1220 tonnes or 39.2 million ounces (Mozs) in 2009.

Australia's Economic Demonstrated Resources (EDR) rose by 1144 tonnes or 26.8Mozs in 2009 to 7399 tonnes and accounted for 82% of total demonstrated resources, a similar proportion to the past three years. In 2009, EDR increased in the NT and all States on the back of continuing high gold prices. Although Western Australia (WA) continued to dominate EDR with 2980 tonnes, its share fell again in 2009 to 40% of national EDR

compared to 47% in 2008 and 49% in 2007. This reduction in share occurred despite WA's EDR increasing by 46 tonnes and again was the result of strong growth in other States, particularly in New South Wales (NSW), South Australia (SA) and the NT.

Subeconomic Demonstrated Resources rose by only 14 tonnes in 2009 with a small increase of 17 tonnes in the Paramarginal Demonstrated Resources category being slightly offset by a reduction of 3 tonnes in the Submarginal Demonstrated Resources. Resources in the Paramarginal category rose to 1495 tonnes with 71% of total Paramarginal Resources occurring in WA. This share also was higher than the 67% in 2008 but similar to the 72% in 2007. The Submarginal Demonstrated Resources fell by 3 tonnes to 120 tonnes, just over half of which was in WA.

Following an increase in 2008, the level of Inferred Resources fell in 2009 by 165 tonnes to 4331 tonnes. WA (45%) and SA (23%) dominate Inferred Resources.

Accessible EDR

EDR for gold are essentially unencumbered with less than 2% is in any form of restricted area. At Australia's 2009 rate of production, EDR is sufficient for about 33 years. Increased production in 2009 was more than offset by increased EDR resulting in a small increase in the estimated production life. Resources classified only as reserves under the Joint Ore Reserve Committee (JORC) Code will support only 16 years at the 2009 production rate, which is a similar period to that in 2008. These estimates are average figures and there are some operations which may continue after these periods and there are others which will close before the end of those periods. However, 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 2009, 48% of EDR fell into the JORC Code reserves.

Exploration

On the basis of calendar year exploration spending reported by the Australian Bureau of Statistics (ABS), gold again received the second largest share of exploration expenditure with iron ore remaining as the dominant target in 2009. Gold exploration spending fell by almost 19% to \$463.3 million and its share of total exploration spending was 23%. Western Australia continued to dominate gold exploration by attracting \$276.8 million (\$52.3 million less than in 2008 and its share of total gold exploration rose from 58% in 2008 to 60% in 2009 on the back of strong growth in spending in the second half of the year. All other jurisdictions, except the Australian Capital Territory, had gold exploration during the year and encouraging results were reported from them.

It should be noted that 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 2008–09 was \$438.1 million, a reduction of \$154.6 million over 2007–08.

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 2009 totalled US\$445.5 million or A\$625 million based on the exchange rate used by the Metals Economics Group (MEG). This budget was about 26% higher than actual spending reported by the ABS. The differences between reported budgets and actual spending on gold exploration is likely to be the result of the impact of the global financial crisis on exploration, particularly in the first half of the year when ABS expenditure data for gold exploration showed levels well under the previous year. The continuing dominance of iron ore is likely to have played a part also as the impact of the financial crisis on iron ore exploration was limited with the continuing strong interest in iron ore from China.

The MEG data show that 40% of gold exploration budgets were expected to be directed at grassroots exploration compared to 36% in 2008 and 47% in 2007. The share of minesite gold exploration budgets reported by MEG

rose in 2009 to 36% compared to 25% in 2008 but late stage gold exploration budgets fell to 24% compared to 39% in 2008. Although there was some recovery in grassroots gold exploration the budgets for 2009 again highlighted the continued concentration on brownfields exploration for gold.

New gold mineralisation was found across the continent and at depth below known deposits in a variety of mineralisation styles. The Archean greenstones of WA's Yilgarn Craton remain a very favourable target, although substantial opportunities exist in other provinces. A major review of the highlights of gold exploration in Australia in 2009 is available in the document *Australian Mineral Exploration: A Review of Exploration for the Year 2009—Extended Edition*, which is available for download from the Geoscience Australia web site. Indicative of drill intersections reported across the country in 2009 which highlight the potential, with further exploration, to yield resources to underpin the Australian gold sector into the medium to longer term are:

Industry developments

NEW SOUTH WALES

Alkane Resources Ltd reported encouraging drill intersections from the **McPhillamys** prospect, 35 kilometres (km) southeast of Orange, where it is in joint venture with Newmont Australia Ltd. An intersection of 299 metres (m) at 1.09 grams per tonne (g/t) Au from 68m included 207m at 1.38g/t Au from 160m and 30m at 3.21g/t Au from 336m. Another hole returned 135m at 1.0g/t Au from 41m and 69.6m at 1.04g/t Au from 225m.

Intersections at the **Dargues Reef** project near Majors Creek reported by Cortona Resources Ltd continued to highlight the potential of the area. At Dargues Reef, an intersection returned 17m at 7.44g/t Au, 5.0g/t Ag and 0.1% Cu. At **Exeter Farm** results included 19m at 6.62g/t Au, 7.0g/t Ag, and 0.13% Cu from 114m and 3m at 7.3g/t Au from 179m.

NORTHERN TERRITORY

Westgold Resources Ltd reported results from the Western Zone at the **Rover 1** project 80km southwest of Tennant Creek, which included 128m at 1.2% Cu, 1.2g/t Au, 2.0g/t Ag, 0.07% Bi, 0.05% Co from 402m and 13m at 3.7% Cu, 0.13g/t Au, 1.6g/t Ag, 0.13% Co from 433m.

QUEENSLAND

The combined Indicated and Inferred Resource at Renison Consolidated Mines NL's **Agate Creek** epithermal gold project is 14.8 million tonnes (Mt) at 1.0g/t Au, at a 0.3g/t Au cut off. Regional mapping within the area has resulted in the identification of new prospects where rock chip sampling returned up to 357g/t Au from the **Phoenix Prospect**; up to 2510g/t Ag, 5.58% Cu, 3.4% Pb and 5.94% Zn from the **Moon Beam Prospect**, and up to 7.77g/t Au from the **Will Scarlet Prospect**.

At the **Cracow** gold mine near Theodore, drilling on the **Kilkenny** prospect produced significant intersections including 12.8m at 14.18g/t Au which included 2m at 79.4g/t Au. Newcrest Mining Ltd has 70% of the project and is the project manager and Lion Selection Ltd has 30%.

SOUTH AUSTRALIA

Southern Gold Ltd's drilling at its **Golf Bore Prospect**, 40km northeast of the Challenger Gold Mine extended down plunge gold mineralised shoots. In the **Golf Bore Prospect Central Zone** intersections reported included 33m at 1.1g/t Au, including 5m at 2.13g/t Au and 9m at 2.26g/t, 27m at 1.15g/t Au and 17 m at 1.0g/t Au. In the South Zone intersections included 13m at 1.01g/t Au from 82m (including 4m at 2.08g/t from 82m) and 19m at 1.04g/t Au from 112m (including 6m at 2.0g/t from 117m).

TASMANIA

Bendigo Mining Ltd reported further extension to mineralisation at the **Henty Gold Mine** with drill intersections including 9.1m at 11.8g/t Au, 3.5m at 34.5g/t Au and 3m at 8.7g/t Au. These were beneath the previously mined Darwin South Zone.

VICTORIA

At the Bendigo Mining Ltd **Kangaroo Flat** mine in Bendigo, a sub-vertical zone of auriferous quartz veining cross-cutting predominant structures was identified. The zone is 10–15m long, 3–5m wide and more than 170m high, with intersections including 3.7m at 105g/t Au and 5m at 10g/t Au.

Northgate Minerals continued near-mine exploration at the **Fosterville** and **Stawell** gold mines. At Fosterville, drilling confirmed that gold mineralisation on the currently mined Phoenix fault system continues both laterally and down plunge, with intersections including 6.7m at 10.1g/t Au. At 30 June 2009, Fosterville had 564 000 ounces (ozs) of contained gold in ore reserves and 1.967Mozs of contained gold in Measured, Indicated and Inferred Resources. At the Stawell mine, an additional 93 000ozs Au ore reserves and 130 000ozs Au resources were delineated in 2009. At 30 June 2009, the Stawell mine had 313 000ozs of contained gold in ore reserves and 435 000ozs of contained gold in Indicated and Inferred Resources.

WESTERN AUSTRALIA

Independence Group NL and its partner AngloGold Ashanti announced an increase in the **Tropicana** open-cut resource, 230km east-south-east of Laverton, from 4.05Mozs Au to 5.01Mozs made up of Measured Resource of 19.9Mt at 2.38g/t Au for 1.53Mozs Au, Indicated Resource of 31Mt at 2.06g/t Au for 2.01Mozs Au and an Inferred Resource of 24.3Mt at 1.83g/t Au for 1.43Mozs Au for a combined resource of 75.3Mt at 2.07g/t Au for 5.01Mozs Au. Following a positive pre-feasibility study the Tropicana Joint Venture approved the start of a Bankable Feasibility Study (BFS) which will focus on a detailed assessment of owner and contract mining options and on optimising capital and operating costs.

Beadell Resources Ltd announced the discovery of a sapolite gold anomaly at its **Neale Prospect** in the Tropicana East project, immediately north of the AngloGold-Ashanti and Independence Group Joint Venture Tropicana tenements. Aircore drill samples returned values of 674 parts per billion (ppb) Au (0.67g/t) and 312ppb Au (0.31g/t) from separate holes in the southern part of the tenement. The company also announced new gold anomalies at **Hercules** and **Pleiades** in the project area.

Beadell Resources Ltd announced that drilling at its **Handpump Prospect** in the West Musgrave Complex in WA near the border with SA intersected significant gold mineralisation in rhyolitic breccia. An intersection of 65m at 0.83g/t Au from 10m depth included a high grade zone of 5m at 5.1g/t Au from 35m depth within a zone of 15m at 2.3g/t Au from a depth of 30m. The company commented that these results represent the first economic gold intersection in the Musgraves.

Production

Australian gold production reported by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) for 2009 was 223 tonnes, an increase of 4% from the 2008 level. Australia's largest producer in 2009 was the Super pit at Kalgoorlie with 0.6Mozs or 19 tonnes. It was followed by the Telfer operation, also in WA where production was almost 0.58Mozs or 18 tonnes. Western Australia continued to dominate Australian production with 152 tonnes, just over two-thirds of total Australian output and an increase of 13% on the output achieved in 2008 (Table 2).

Table 2. Australian gold production 2005 to 2009.

	2005 (t)	2006 (t)	2007 (t)	2008 (t)	2009 (t)
New South Wales	28.05	27.04	34.89	31	25
Victoria	5.24	6.27	6.42	5	8
Queensland	23.99	21.47	20.81	18	16
South Australia	6.24	6.75	6.92	7	8
Western Australia	173.14	165.10	155.29	134	152
Tasmania	8.34	5.10	4.19	5	4
Northern Territory	16.55	14.03	16.54	15	10
Australia	261.53	245.76	245.04	215	223

Source: ABARE-BRS Australian Commodity Statistics 2008 and ABARE-BRS Australian Mineral Statistics, March Quarter 2010

World Ranking

The United States Geological Survey (USGS) estimate world gold reserves remained unchanged at 47 000 tonnes in 2009. According to the USGS, South Africa has the world's largest reserve of gold which remained unchanged at 6000 tonnes accounting for 12.8% of world reserves. The USGS estimates Australia has the second largest reserve with 12.3% followed by Russia with 10.6%.

Data published by the USGS shows world mine production of gold in 2009 to be 2350 tonnes, an increase of 90 tonnes on the estimated 2008 production level. China remained the leading producer with 300 tonnes followed by Australia with 220 tonnes and South Africa and the USA each with 210 tonnes.

Industry Developments

A limited review of developments is available in the document *Australian Mineral Exploration: A Review of Exploration for the Year 2009—Extended Edition*, which is available for download from the Geoscience Australia web site. For a more comprehensive discussion of project development the ABARE-BRS report *Minerals and Energy - major development projects—October 2009 listing* is available for download from the ABARES website.

Some of the major developments are:

- Boddington (Newmont 100%) in WA where milling was expected to start in late in 2009 with production over the first five years expected to average around 1.0Mozs a year. Average annual production over the current 15 year life of mine will be around 850 000ozs of Au and 30 000 tonnes of Cu. Production at Boddington has started.
- Kagara Ltd was constructing the Mungana mine in north Qld and production has commenced. Annual output from the project is expected to be around 80 000ozs.
- Exco Resources Ltd's White Dam project in SA about 50km west of Broken Hill is expected to yield around 50 000ozs a year when it reaches full capacity in 2010.
- Catalpa Resources Ltd is redeveloping the Edna May mine in WA. At full production the mine is expected to produce around 100 000ozs of gold annually.
- In addition there are a number of existing operations which are being expanded including the Challenger mine in SA, Ridgeway Deeps in NSW and the Homestead underground operation at Paddington and the Athena underground mine at St Ives in WA.

Iron Ore

Ron Sait (contact aden.mckay@ga.gov.au)

Iron (Fe) is a metallic element which constitutes about 5% of the Earth's crust and is the fourth most abundant element in the crust. Iron ores are rocks from which metallic iron can be economically extracted. The principal iron ores are hematite (Fe_2O_3) and magnetite (Fe_3O_4). Almost all iron ore is used in blast furnaces to make pig iron which is the main material in steelmaking. Small amounts of iron ore are used for example in coal washeries and in cement manufacturing. Iron can be alloyed with a variety of elements to produce stronger and harder products which are useful in the construction industry and in the manufacture of motor vehicles, ships, trucks, pipelines, trains and railway tracks. Iron is the most used metal accounting for about 95% of the total metal tonnages produced worldwide.

Western Australia (WA) dominates the Australian iron ore industry with nearly 97% of the total production.

The Pilbara region is particularly significant with 79.5% of Australia's total identified resources and 92.4% of the production. Locally significant iron ore mines also operate in the Northern Territory (NT), South Australia (SA), Tasmania (Tas), Queensland (Qld) and New South Wales (NSW).

Resources

In 2009 Economic Demonstrated Resources (EDR) increased by 16.7% to 28 gigatonne (Gt) mainly due to the inclusion of Iron Valley, Rocklea (Murchison Metals), Spinifex Ridge, Turee Syncline and Wodgina (Atlas Iron) for the first time and large increases at the Cloud Break, Jack Hills, Marillana and Solomon deposits. Western Australia has 98% of Australia's EDR with about 80.7% occurring in the Pilbara district. Magnetite ore in 2009 constituted 34% or 9.5Gt of Australia's EDR with 94.7% occurring in WA.

Paramarginal Demonstrated Resources remained constant at 0.3Gt and Subeconomic Demonstrated Resources increased 19.5% to 1.9Gt mainly because of remnant ore lying outside the pits at the Balmoral Southern and Ridley deposits in WA. Inferred resources increased by 15.9% to 33.5Gt because of large increases at Jack Hills, Jimblebar, Marillana, Mining Area C and Ridley and the addition of 10 new deposits, including Iron Valley, Mount Oscar, Beyondie and Irvine Island for the first time. Magnetite ore in 2009 constituted 27% or 9Gt of Australia's Inferred Resources with 82% occurring in WA. Western Australia also has about 93% of Australia's total identified resources of iron ore with 79.5% 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 27.9Gt is about 70 years. Without magnetite ore, accessible EDR is 18.5Gt, reducing the resource life to about 50 years.

JORC Reserves

About 44% of accessible EDR, or 12.3Gt, is Joint Ore Reserve Committee (JORC) Code reserves compliant. The resource life of JORC Code reserves is about 30 years. Rio Tinto, BHP Billiton and Fortescue Metals Group manage 61% of the JORC Code reserves and magnetite ore constitutes 28.5% of the JORC Code reserves. Without magnetite ore JORC Code reserves are 8.8Gt reducing the reserve life to about 23 years.

In 2009, many new deposits were added to Australia's iron ore resource base including, Daltons, Iron Valley, Irvine Island, Mount Webber, Mount Finnerty, Mount Oscar, Rocklea (Murchison Metals), Spinifex Ridge, Turner River, Wodgina (Atlas Iron), Delta (Flinders Mines), Caramulla South, Anthiby Well, Turee Creek Syncline, Beyondie all in WA, Cobar in NSW, Warramboe in SA, Mount Peake in the NT and Ernest Henry in Qld.

Exploration expenditure

The Australian Bureau of Statistics (ABS) data indicates that exploration expenditure for iron ore in 2009 totalled \$521.2 million, a 10.6% decrease on the \$583.0 million spent in 2008. About \$500.3 million, or 96%, was spent in WA. Iron ore exploration accounted for 25.8% of the total mineral exploration expenditure in Australia in 2009.

Production

The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) reported that Australia's iron ore production in 2009 was 393.9Mt (341.1Mt in 2008) with 97% produced in WA. Exports in 2009 totalled 362.4Mt (310.2Mt in 2008) with a value of \$30 billion. In 2009 ABARE projected that Australia's iron ore production will increase to 504.9Mt by 2013/14 while, during the same period, exports are projected to rise to 473.5Mt.

World ranking

In 2009 Australia had about 17% of world EDR of iron ore and was ranked second after Ukraine (18%). In terms of contained iron, Australia has about 18% of the world's EDR and is ranked first with Russia second (18%). Australia produces around 17% of the world's iron ore and is ranked second behind China (39%).

Industry Developments

WESTERN AUSTRALIA.

Rio Tinto Iron Ore: The \$1.2 billion Mesa A Project commenced operations in early 2010 at an initial production rate of 20 million tonnes per annum (Mtpa) rising to 25Mtpa in 2011. The \$200 million Western Turner Syncline Project is expected to produce 6Mtpa from mid-2010. The \$2 billion Brockman Syncline 4 project is scheduled to be commissioned by late 2010 with a capacity of 22Mtpa.

BHP Billiton: The \$2.5 billion Rapid Growth 4 (RGP4) Newman Hub commenced operations in December 2009 increasing capacity by 26Mtpa to 155Mtpa. The \$5.6 billion Rapid Growth Project 5 (RGP5) is planned to provide an additional 50Mtpa of capacity and is expected to be commissioned in late 2011. The \$2.2 billion Rapid Growth Project 6 (RGP6) is expected to increase capacity to 240Mtpa from 2013.

Fortescue Metals Group (FMG): In February 2009, mining commenced at the Christmas Creek deposit. FMG plans to spend \$360 million at the Chichester Hub to expand production from 35 to 55Mtpa in 2011. The proposed Stage 1, \$3.5 billion Solomon Hub FMG is planned to produce 20Mtpa of Brockman ore and 40Mtpa of CID (Channel Iron Deposit) ore.

Hancock Prospecting: The 30Mtpa Hope Downs 4 Project is expected to commence in 2012. At the \$7.3 billion Roy Hill 1 Project a 55Mtpa Marra Mamba ore operation is planned to commence in 2013. Construction is expected to begin in 2011 and will include a rail line and an export terminal at Stanley Point at Port Hedland.

Cliffs Natural Resources: At Cockatoo Island, production is expected to resume in the first half of 2011 when the seawall is completed. The company is planning to expand the Koolyanobbing Project to include an additional mining operation at the Mount Jackson J1 Deposit. In 2009, Cliffs completed an upgrade of the rail line to the Port of Esperance.

Mount Gibson Iron Ltd: Construction at the \$80 million Extension Hill DSO project recommenced in January 2010. Production is expected to commence in mid-2010 at a rate of up to 3Mtpa.

Murchison Metals Ltd: The Stage 2 Jack Hills Expansion Project is planned to produce up to 25Mtpa of Direct Shipping Ore (DSO) and Beneficiated Feed Ore (BFO). First production is being targeted to coincide with commissioning of a new 560km rail line to a new port at Oakajee in 2013.

Sinosteel Midwest Corporation: The Koolanooka/Blue Hills DSO project commenced operations in early 2010 at a production rate of about 1.5Mtpa over 5 years. Sinosteel is planning a 15Mtpa DSO operation at Weld Range.

Atlas Iron Ltd: The \$10 million Wodgina DSO Project is to commence operations in mid-2010 at a rate of 3.6Mtpa. The Pardoo Project is being upgraded from 1.1 to 2.5Mtpa from late 2010 costing \$14.5 million. Atlas is planning a 3Mtpa operation at the Abydos Project. The \$2.7 billion Ridley Project is planned to produce 15Mtpa of magnetite concentrates.

Aurox Resources Ltd: The \$1.3 billion Balla Balla Project is initially planned to produce 6Mtpa of magnetite concentrate and 280 kilotonne per annum (ktpa) of titanium concentrate from 2012.

CITIC Pacific Mining: First production from the \$5.2 billion Sino Iron Project is expected in late 2010. The project is planned to export 27.6Mtpa of magnetite concentrates and pellets. Infrastructure includes a 450 megawatt gas fired power station, a desalination plant and a port at Cape Preston.

Gindalbie Metals Ltd: Construction of the \$2 billion Karara Project commenced in November 2009. Stage 1 is planned to produce 3Mtpa of hematite from mid-2011 and 8Mtpa of magnetite concentrates from late 2011. Initially products will be exported through the Port of Geraldton.

BC Iron Ltd: Mining at the 3Mtpa Nullagine Project is expected to start in late 2010 with first shipments in December 2010.

Grange Resources Ltd: The \$1.6 billion Southdown Project is expected to produce 6.6Mtpa of magnetite concentrates from 2013 and includes a 100km slurry pipeline to the Port of Albany.

Australasian Resources Ltd: The Balmoral South Project is expected to produce 24Mtpa of magnetite concentrates with 14Mtpa being pelletised.

China Metallurgical Group Corporation: The Cape Lambert Project near Karratha is planned to produce 15Mtpa of magnetite concentrates.

Asia Iron Pty Ltd: The Extension Hill Magnetite Project is planned to produce 10Mtpa of concentrate and includes a 280km slurry pipeline to Geraldton.

Golden West Resources Ltd: The Stage 1 \$15 million Wiluna West project is planned to export 1Mtpa of DSO through Esperance from 2011.

Ferrowest Ltd: The Yalgoo Iron Project is planned to produce pig iron from 2012 utilising magnetite from the Yogi deposit.



Iron ore mining at the Green Pit, Western Australia (Fortescue Metals Group)

Australian Premium Iron Ore Joint Venture: The proposed \$4 billion Stage 1 West Pilbara Project is planned to produce 30Mtpa of DSO from 2013.

Iron Ore Holdings Ltd: The Phil's Creek Project is planned to supply up to 1.5Mtpa of DSO from late 2010 to Rio Tinto under a mine gate sale arrangement.

Brockman Resources: The proposed \$1 billion Marillana Project is expected to produce 20Mtpa from 2013.

Mineral Resources Ltd: The \$120 million Stage 1 Yilgarn Project is expected to produce an initial production of 1.5Mtpa from the Carina deposit in 2011. The Poondano Project is planned to produce an initial 850ktpa from 2011.

Moly Mines Ltd: Construction at the \$9.4 million Spinifex Ridge Project commenced in May 2010. The 1Mtpa DSO operation is expected to start in late 2010 over an initial five year mine life.

Cazaly Resources: The \$78 million Parker Range Project is planned to produce 4Mtpa of DSO from late 2011 with exports via Kwinana.

Giralia Resources: The \$115 million Mount Webber Project is planned to produce 2Mtpa.

FerrAus Ltd: The Davidson Creek and Robertson Range Projects are planned to initially produce 15Mtpa.

SOUTH AUSTRALIA.

OneSteel Ltd: Project Magnet Phase 2 includes mine optimisation and mine extension drilling. OneSteel is proposing to open the new Iron Chieftan mine and reopen dormant mines around Iron Knob.

Western Plains Resources Ltd: The \$62 million Peculiar Knob Project is expected to commence operation in late 2011 at a rate of up to 3Mtpa.

IMX Resources: The \$15 million Phase 1 operation at Cairn Hill is expected to produce about 1.4Mtpa of magnetite ore for export from late in 2010.

Centrex Metals Ltd: The proposed 2Mtpa Wilgerup DSO project is expected to commence in 2010.

Ironclad Mining Ltd: The \$45 million Stage 1 Wilcherry Hill Project is planned to produce 2Mtpa of DSO from late 2010.

TASMANIA.

Grange Resources Ltd: The Savage River Project produces 2.6Mtpa of magnetite pellets and concentrates and the current mine plan has a 14 year life with potential to extend an additional 10 years.

Shree Minerals: The proposed \$25 million Nelson Bay River Project is planned to produce 150ktpa of magnetite concentrates, mainly for use in coal washeries.

NORTHERN TERRITORY.

Territory Resources Ltd: In March 2010 at the Frances Creek Project a new crushing and screening plant was commissioned to provide improved consistency and reliability.

QUEENSLAND

Curtain Brothers: At Mount Moss oxide lump ore has been stockpiled ready for export through the Port of Townsville. Magnetite also is being sold to coal washeries.

Xstrata Copper: The \$590 million Ernest Henry life extension project is planned to produce 1.2Mtpa of magnetite concentrates from 2012.

Industry Developments

IRON AND STEEL

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

- **Bluescope Steel Ltd:** Steel production at Port Kembla (NSW).
- **OneSteel Ltd:** Steel production at Whyalla (SA), Rooty Hill and Mayfield (NSW) and Laverton North (Vic).
- **HIs melt:** The HIs melt facility at Kwinana (WA) is on care and maintenance.
- **Ferrowest Ltd:** At the Yalgoo (WA) pig iron project an initial 500ktpa is planned to be produced from 2012. Ferrowest plan to use the Midrex Technologies ITmk3 process.
- **Boulder Steel Ltd:** The \$2.1 billion Gladstone Steel Project (Qld) is planned to use blast furnace/basic oxygen furnace technology to produce 5Mtpa of steel billets, bloom and slab for downstream finishing in rolling mills in the Middle East.

Lithium

Roy Towner (roy.towner@ga.gov.au)

Lithium (Li) is recovered from the mineral spodumene ($\text{Li}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2$) and lithium-rich brines.

It is used in a range of products such as ceramics, glass, batteries and pharmaceuticals. Lithium use 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 recovered from the production of spodumene from the Greenbushes mine in southwest Western Australia (WA) has been used in the production of specialty glasses, glass bottles, ceramics and ceramic glazes. Spodumene 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 4% in 2009 to 607 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. Other EDR of lithium occur at Mount Marion about 40km southwest of Kalgoorlie, WA, in a number of outcropping spodumene pegmatites, and at the Mount Cattlin spodumene mine about 2km north of Ravensthorpe, WA.

In 2009, Subeconomic Demonstrated Resources of lithium, all in the Submarginal category and all in WA, total less than one kilotonne (kt).

Inferred Resources total 37kt and are associated with the Mount Cattlin and Mount Marion pegmatite deposits in WA.

Accessible EDR

All of Australia's EDR of lithium is accessible.

JORC Reserves

Joint Ore Reserve Committee (JORC) Code reserves comprise total lithium in Proved and Probable Ore Reserves as defined in the JORC Code. In 2009, JORC Code reserves of 58kt accounted for approximately 10% of Accessible Economic Demonstrated Resources (AEDR). At Australia's 2009 rate of spodumene production, lithium reserves in the JORC Code reserves categories are adequate for about 18 years.

Exploration

There are no statistics available on exploration expenditure for lithium. However there are only a few companies exploring for lithium mainly in WA and Queensland (Qld).

Production

According to the WA Department of Mines and Petroleum, the Talison Minerals' Greenbushes operation produced 197 482 tonnes of spodumene concentrate in 2009, containing between 4.8% and 7.5% lithium oxide (Li₂O).

World Resources

According to estimates by the United States Geological Survey (USGS) which have been modified by Geoscience Australia for Australia's resources, world lithium resources in 2009 totalled about 9930kt. The resource data does not include Portugal. According to the USGS, of the total world resources, Chile holds approximately 7500kt, or 76% of the total, followed by Argentina with 800kt, Australia with 607kt, China with 540kt, Brazil with 190kt and Canada with 180kt.

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

World production in 2009 was estimated by the USGS to be 18kt of contained lithium, excluding the USA production for commercial reasons. Based on the USGS data, Chile produced about 7.4kt to remain the world's largest producer in 2009 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 batteries to power hybrid and electric cars. Lithium batteries are the preferred choice for electric car manufacturers over the nickel metal hydride batteries in terms of higher power output, durability and cost.

Talison Lithium has two processing plants, one producing technical-grade lithium concentrates and one producing chemical-grade lithium concentrate, located at its **Greenbushes** mine in WA. The processing operations were upgraded in early 2009 to the current nominal capacity of 600 000 tonnes per annum (tpa) of ore feed yielding about 260 000tpa of lithium concentrate. The 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 is consumed by their glass, ceramics, steel, and foundry industries. The Greenbushes mine has a reported lithium mineral reserves of 9.6 million tonnes (Mt) grading 3.9% Li₂O and a combined Measured and Indicated Resource of 22Mt grading 3.7% Li₂O.

Galaxy Resources Limited has commenced mining ore from the Dowling Pit at its **Mount Cattlin** lithium project (hard-rock spodumene) near Ravensthorpe in WA. It began commissioning its onsite processing plant in September 2010 and the first shipment of spodumene to China is expected in fourth quarter 2010. When in full production, the project will produce 137 000tpa of 6% Li₂O spodumene concentrate for an expected mine life of 16 years. Galaxy Resources has received approval from the Chinese Government to start construction of its lithium carbonate plant in Jiangsu Province in China. This plant will produce 17 000tpa of lithium carbonate. The Mount Cattlin

deposit has a reported JORC Code compliant resource of 14.4Mt with average grade of 1.08% Li₂O and 153 parts per million of tantalum pentoxide (Ta₂O₅) containing an estimated 155 000 tonnes of Li₂O and 219 000 tonnes of Ta₂O₅.

Reed Resources Ltd and joint venture partner Mineral Resources Limited announced plans to commence production at their **Mount Marion** Lithium project, 40km southwest of Kalgoorlie, WA, in the first quarter of 2011 at an initial rate of 200 000tpa of spodumene concentrate grading at 6.5% Li₂O, containing about 13 000 tonnes of Li₂O. The project has a total contained Li₂O resource of 128 000 tonnes.

Magnesite

Roy Towner (roy.towner@ga.gov.au)

Magnesite (magnesium carbonate MgCO₃) is marketed in three main forms:

- crude magnesite, primarily for use in chemicals and agriculture,
- dead-burned magnesia, a durable refractory used in the cement, glass, steel and metallurgical industries, and
- 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 decreased by 4% to 330 million tonnes (Mt) in 2009 down from 344Mt in 2008. South Australia (SA) remained Australia's largest holding of EDR with 235Mt of magnesite, which is unchanged from 2006. The bulk of these resources, which occur as interbeds of sedimentary magnesite within the Skilloalee Dolomite, are located at the Witchelina and Mount Hutton deposits, up to 30 kilometres (km) northwest of Leigh Creek. The average magnesite grade is 40% magnesium oxide (MgO).

Queensland (Qld) has Australia's second largest inventory with 63Mt of magnesite EDR. The bulk of this resource occurs at Kunwarara 70km northwest of Rockhampton, where Queensland Magnesia Pty Ltd has global resources of 1200Mt of magnesite bearing material. Within this global resource, which has an Inferred Resource of 500Mt of magnesite, several high-grade magnesite zones have been classified as EDR. The Kunwarara deposit occurs as sheet-like lenses of magnesite with an average thickness of 7.6 metres (m) extending over an area of about 63 square kilometres. It contains four high-grade zones of very high-density bone-type, low iron ultrafine-grained cryptocrystalline to microcrystalline nodular magnesite.

The third largest inventory of EDR is in Tasmania (Tas) where the Arthur River deposit has a measured resource of 13.2Mt with an average magnesite grade of 43.4% MgO. The resource is part of a much larger global resource of 195Mt in the Arthur-Lyons River area, about 53km south of Burnie.

The remainder of Australia's EDR occurs in the Winchester deposit 70km south of Darwin in the Northern Territory (NT), at Thuddungra 80km northwest of Young in New South Wales (NSW), and at Bandalup 20km east of Ravensthorpe in Western Australia (WA).

Subeconomic Demonstrated Resources of 57Mt of magnesite remained unchanged from 2006. All of these resources occur at Triple Four in central Qld and at Main Creek in Tas.

Inferred Resources of magnesite decreased in 2009 to 826Mt (931Mt in 2008) with Qld accounting for 56% followed by SA with 35% and Tas with 5%. The remaining resources are in NSW, the NT and WA.

Accessible EDR

All magnesite EDR is accessible for mining.

JORC Reserves

Joint Ore Reserves Committee (JORC) Code reserves comprise total magnesite in Proved and Probable Ore Reserves as defined in the JORC Code. In 2009, JORC Code reserves of 37.5Mt accounted for approximately 11% of Accessible Economic Demonstrated Resources (AEDR). At Australia's 2008 rate of production, magnesite resources in the JORC Code reserves categories are adequate for almost 109 years.

Exploration

Data associated with 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 2008–09, the company produced a total 344 962 tonnes of magnesite. Some 3273 tonnes of magnesite was produced from the Myrtle Springs region in SA in 2009. The United States Geological Survey (USGS) data indicated that China (56%), Turkey (12%), and Russia (7%) were the world's largest producers of magnesite in 2009.

World Ranking

According to Geoscience Australia and USGS data, Australia has about 5% of the world's EDR of magnesite with Russia, North Korea and China jointly accounting for almost 65% of the world's EDR. The Kunwarara deposit in Qld is the world's largest known resource of ultrafine-grained cryptocrystalline to microcrystalline nodular magnesite.

Industry Developments

Following the completion of its third multiple hearth furnace in 2009, Queensland Magnesia Pty Ltd production of magnesia increased significantly from 125 kilotonne (kt) in 2008–09 to 345kt in 2009–10.

Korab Resources Limited is in negotiations with syndicates of financiers and building material suppliers on the development of the Winchester magnesium project in the NT as a supplier of MgO-based products. MgO is used extensively in Canada and the USA to produce low-cost, high-strength building materials which do not expand or shrink when submerged in water or heated. The project has a JORC Code Indicated Resource of 12.2Mt grading 43.1% MgO.

Beacon Hill Resources Plc has been granted a mining lease to develop the Arthur River magnesite deposit. The company is aiming to complete a development proposal and Environmental Management Plan by the end of 2010, with production planned to commence by the end of 2011.

Manganese Ore

Michael Sexton (michael.sexton@ga.gov.au)

Manganese is the twelfth most abundant element in the earth's crust and the fourth most used metal in terms of tonnage, after iron, aluminium and copper. Over 90% of world manganese production is used as an alloying agent for the desulphurisation and strengthening of steel. After steel, the second most important use for manganese is in the form of electrolytic manganese dioxide (EMD) in dry-cell batteries. It is also an additive in plant fertilisers and a colorant for bricks.

In Australia there are three operating mines and one tailings re-treatment plant. The Northern Territory has two manganese mines with one located on Groote Eylandt in the Gulf of Carpentaria and the other at Bootu Creek 110km north of Tennant Creek. The Woodie Woodie mine is located about 400km southeast of Port Hedland in Western Australia. A manganese tailings processing plant also operates near the Woodie Woodie mine. There is also a small mining operation at Ant Hill that has begun trial shipments of ore. 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 2009 Australia's Economic Demonstrated Resources (EDR) of manganese ore remained steady at 181Mt with increases in EDR at Ant Hill and Bootu Creek offsetting falls in EDR at Groote Eylandt. Paramarginal Demonstrated Resources remained unchanged at 23Mt and Subeconomic Demonstrated Resources also remained unchanged at 167Mt. Inferred resources increased 0.6% to 134Mt mainly due to an increase at Ant Hill.

Accessible EDR

All manganese ore EDR (181Mt) is accessible. The resource life is about 21 years on current rates of production of beneficiated manganese ore.

JORC Reserves

Manganese ore Joint Ore Reserve Committee (JORC) Code reserves are 146Mt (81% of accessible EDR). The resource life based on JORC Code 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.

Production

The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) reported that Australia produced 4.45Mt of beneficiated manganese ore in 2009 (4.8Mt 2008). Exports for 2009 totalled 4.7Mt (4Mt 2008) valued at \$996 million (\$2,021 million in 2008).

World ranking

Australia has 13% of the world's EDR of manganese ore and is ranked fourth behind Ukraine (29%), South Africa (20%) and China (14%). Australia produces 14% of the world's manganese ore and is ranked second behind China (39%).

Industry developments

NORTHERN TERRITORY

GEMCO: The US\$180 million expansion project on Groote Eylandt was completed in the first half of 2009. The installed capacity was increased by 1Mtpa to 4.1Mtpa of manganese concentrates. In 2009 GEMCO commenced drilling program for manganese ore within the mining lease, and plan to explore the eastern leases.

OM Holdings Ltd: In December 2009, a secondary processing plant was commissioned which increased production capacity to about 800ktpa of concentrates. OM Holdings announced in late 2009 the capacity of the secondary processing plant would be increased to 250ktpa. This will result in an annual production target for 2010 of 1Mt, comprising 750kt of 38% grade and 250kt of 35% grade products. A \$3 million exploration program was completed in 2009 at the Helen Springs and Renner Springs Projects, together with minor extension and infill drilling of existing mineral resources.

WESTERN AUSTRALIA

Consolidated Minerals Ltd: The Woodie Woodie mine has a capacity of 1.1Mtpa heavy media separation plant, which produces lump and fine products that are transported by 90 tonnes road trains some 400km to Port Hedland where blending occurs prior to overseas shipment. The Woodie Woodie product has a high manganese content and low phosphorus and iron levels, which is used for stainless steel and ferro-alloy production.

Mineral Resources Ltd: A 400ktpa tailings re-treatment plant operates at Woodie Woodie and a 240ktpa plant operates at Peak Hill. The project produces a +50% ferruginous manganese product for export through Port Hedland. Product shipped in 2009 was down to 212kt of lump and fine manganese ore from Woodie Woodie and Peak Hill. A collaborative project with Hancock Prospecting at Balfour Downs is planned to commence operation in the 2010 financial year, with a target of around 500ktpa of product, using the Mineral Resources developed mobile beneficiation circuit.

Mesa Minerals Ltd: The Ant Hill project is located approximately 400km south of Port Hedland. Trial shipments of ore have been delivered to two Chinese customers. Mesa has secured initial port capacity at Utah Point in Port Hedland for 300ktpa of ore exports once the port opens in late 2010.

Mineral Sands

Yanis Miezitis (yanis.miezitis@ga.gov.au)

The principal components of mineral sands are rutile (TiO_2), ilmenite (FeTiO_3), zircon (ZrSiO_4) and monazite ($[\text{Ce,La,Th}]\text{PO}_4$). Rutile and ilmenite are used predominantly 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 to generate electricity in thorium nuclear reactors.

Resources

Economic Demonstrated Resources (EDR) of ilmenite decreased by 5.6% to 200.4 million tonnes (Mt) in 2009, down from 212.3Mt in 2008. About 54% of Australia's EDR of ilmenite is in Western Australia (WA) and 21% is in Queensland (Qld) with the remainder in Victoria (Vic), 11.9%, New South Wales (NSW), 9.7% and South Australia (SA), 3.1%.

EDR of rutile, which includes some leucoxene in WA, decreased by 0.9% from 22.9Mt in 2008 to 22.7Mt in 2009. Victoria has the largest share of Australia's rutile EDR with 32.6% followed by Qld (25.1%), NSW (19.7%), WA (19.0%) and SA (3.3%).

EDR of zircon increased from 39.2Mt in 2008 to 40Mt in 2009 with WA (32.6%), Vic (22.7%) and Qld (20.4%) accounting for most of Australia's zircon EDR. The balance was in SA (15.0%) and NSW (9.1%).

Australia's Subeconomic Demonstrated Resources of ilmenite, rutile and zircon in 2009 amounted to 30.2Mt of ilmenite, which was an increase of 26.9% on 2008, 7.1Mt of rutile, an increase of 7.6% on the previous year, and 10.4Mt of zircon, an increase of 4% on 2008.

Inferred Resources of ilmenite increased by 3.2% in 2009 to 127.1Mt. Victoria has the largest proportion of inferred ilmenite resources with 51.6% of the Australian total followed by NSW (21.8%), Qld (11.6%) and WA (10.5%).

Inferred Resources of rutile decreased to 31.3Mt from 32.1Mt in 2008. Victoria has the largest share of Australia's inferred rutile resources with 56.9% of the Australian total followed by NSW (28.1%), Qld (6.1%), SA (5.6%) and WA (3.2%).

Inferred Resources of zircon decreased to 34.3Mt from 36.5Mt in 2008. Victoria is the main holder of zircon Inferred Resources with 63.4% of the Australian total, followed by NSW (18.5%), Qld (8.0%) and WA (5.8%).

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, 15% of rutile and 16% 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 17% of ilmenite, 26% rutile and 26% zircon of Accessible Economic Demonstrated Resources (AEDR) comprise Joint Ore Reserve Committee (JORC) Code reserves. The remaining AEDR 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 Securities Exchange.

Duration of Resources

At the rate of production in 2009, Australia's AEDR of ilmenite, rutile and zircon is sufficient for an average of 109 years for ilmenite (86 years in 2008), 69 for rutile (53) and 71 for zircon (56). However, resources in the JORC Code reserves categories are adequate for only 18 years for ilmenite (21 years in 2008), 18 for rutile (16), and 18 for zircon (19). The increases in resource life based on the AEDR is due to the flow-on effects of the global financial

crisis of late 2008 which led to falling demand and lower levels of production of ilmenite, rutile and zircon in 2009 when compared to the production of the three commodities in 2008.

Exploration

According to quarterly Australian Bureau of Statistics (ABS) figures, expenditure on exploration for mineral sands in 2009 decreased to \$28.4 million compared with \$37.5 million in 2008.

Production

In 2009, Australia produced 1.534Mt of ilmenite, 280 000 tonnes of rutile, 166 000 tonnes of leucoxene and 476 000 tonnes of zircon compared with 2.042Mt of ilmenite, 325 000 tonnes of rutile, 158 000 tonnes of leucoxene and 550 000 tonnes of zircon in 2008. About 1.778Mt of ilmenite was exported during 2009 while rutile (587 000 tonnes) and zircon (744 000 tonnes) exceeded the level of production for the two commodities. The ilmenite not exported was upgraded to synthetic rutile containing about 92–94% TiO₂. In 2009, Australia produced 616 000 tonnes of synthetic rutile compared with 511 000 tonnes in 2008.

According to Iluka, global consumption of high grade titanium feedstocks are estimated to have fallen by 20% in 2009 although there were signs of recovery in the second half of 2009 and rebuilding of inventories is expected in 2010. Similarly, there was a reduction of about 25% in global demand for zircon in 2009. Iluka concluded that mineral sand commodity prices would have to be significantly higher to support new mineral sand projects.

World Ranking

According to Geoscience Australia and the United States Geological Survey (USGS) data, Australia's EDR of rutile and zircon represent the world's largest economic resources with 49%, and 46%, respectively. Australia also has the second largest share of the world's ilmenite with 16%, behind China, which has 30%. Other major country rankings include India (13%), Brazil (7%) and South Africa (10%) for ilmenite, South Africa (18%) and India (16%) for rutile and South Africa (25%) and Ukraine (7%) for zircon.

In 2009, world production of ilmenite decreased by 12.5% to 9.1Mt, rutile decreased by 17.3% to 516 000 tonnes, and zircon decreased by 32% to 1.193Mt. Australia is the largest producer of rutile with about 54% of the world production followed by South Africa with 19% and Sierra Leone with 12%. Australia is the second largest producer of ilmenite also with 17% after South Africa with 21% and is the largest producer of zircon with 40% followed by South Africa with 33%.

Industry Developments

Companies which produced heavy mineral sands during 2009 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. However, mining was discontinued from the recently commissioned Mindarie heavy minerals project held by Australian Zircon NL in SA while work restarted at the Matilda Zircon Limited deposits 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 and in the State's southwest region south of Perth.

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 has upgraded its Narngulu plant to process heavy mineral concentrates (HMC) from its **Jacinth-Ambrosia** deposits in the Eucla Basin in SA.

Iluka continued with its restructuring of its heavy mineral facilities in WA by reducing its production capability in WA by 50%. Eneabba mining operations were idled, the southwest ilmenite mining ceased and zircon production in southwest region was transported to Narngulu in the mid-west. Because of weaker demand for its products in 2009, Iluka decided to idle three of its four synthetic rutile kiln plants.

The production of heavy mineral sand commodities in 2009 from Iluka's mining and processing activities in WA, now referred to as the Perth Basin, amounted to 61 000 tonnes of rutile, 405 000 tonnes of synthetic rutile,

643 000 tonnes of ilmenite, 6000 tonnes of Hiti which is a mixture of rutile and leucoxene, and 146 000 tonnes of zircon.

Iluka Resources Ltd's **Douglas** project in western 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 capacity of the Hamilton mineral separation plant was upgraded in order to process additional feedstock from the Murray Basin Stage 2 development at Kulwin. Production from the Murray Basin operations in 2009 totalled 66 000 tonnes of rutile, 13 000 tonnes of ilmenite and 70 000 tonnes of zircon.

The Murray Basin Stage 2 development is based on a group of deposits at Ouyen in northwest Vic, with two-thirds of Iluka's heavy mineral resources in Murray Basin at Kulwin, Woorneck, Rownack, Rainlover, and Pirro along with another group at Euston in NSW named Castaway, Kerribee, Earl, Dispersion and Koolaman. The first production of heavy mineral concentrates from the Murray Basin Stage 2 commenced at the Kulwin mine in October 2009 and full-scale production was reached by mid 2010.

In the Eucla Basin in SA, Iluka operates the **Jacynth-Ambrosia** mine and owns the Gulliver's and Tripitaka deposits. Mining commenced at the Jacynth-Ambrosia mine during the December 2009 quarter with the first production of heavy mineral concentrates in November and reached full-scale production rates of 300 000 tonnes per annum (tpa) of zircon concentrates in the first half of 2010. The heavy mineral concentrates from Jacynth-Ambrosia mine will be processed for mineral separation at Iluka's upgraded Narngulu Plant 2 in the mid-west region of WA. Iluka is continuing to explore the Mojave deposit and announced an initial Inferred Resource for its Typhoon deposit amounting to 1.34Mt of heavy minerals with 76% of ilmenite+leucoxene and 14% zircon.

Consolidated Rutile Limited, which operated the **Yarraman** and **Enterprise** heavy mineral sand mines on North Stradbroke Island, was taken over by Unimin Australia Limited in mid 2009. There has been no published information on the production of heavy minerals or resources of heavy minerals for 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 2009 was approximately 414 000 tonnes of ilmenite, 66 000 tonnes of zircon, 32 000 tonnes of rutile, 28 000 tonnes of leucoxene, 218 000 tonnes of synthetic rutile and 106 000 tonnes of TiO₂ pigment. Exxaro is funding a \$118 million Tiwest Kwinana pigment expansion project for an additional 40 kilotonnes per annum (ktpa) production. The plant was successfully commissioned in July 2010 and ramp-up to planned production levels is expected to be reached by mid 2011.

The heavy mineral resources/reserves held by Bemax Resources Limited (a controlled entity of Cristal Australia Pty Ltd) are located in old shorelines in two provinces—the Murray Basin of Vic and NSW, and the southwest region of WA.

Bemax's operations in the Murray Basin include the **Ginkgo** mine and the Broken Hill mineral separation plant. The development of the **Snapper** mine, 10 kilometres (km) southwest of Ginkgo was well advanced at the end of 2009 and, in December 2009, regulatory approval was received from the New South Wales Government to commence mining a high grade zone ahead of the dredge path and truck the ore to Ginkgo mine for processing. Commissioning plans for the Snapper mine were finalised by mid 2010.

Bemax reported that its total resource in the Murray Basin increased from 94.4Mt of contained heavy mineral in 2008 to 95.1Mt of contained heavy mineral in 2009. The change in resource figures were the result of additional drilling at the Gallipoli deposit but this was partially offset by mining at the Ginkgo mine and decreases in resources at the Laburnum and Crayfish deposits.

Bemax's Ginkgo production in 2009 totalled 128 769 tonnes of ilmenite, 99 470 tonnes of other titanium minerals, 56 604 tonnes of rutile and 48 355 tonnes of zircon.

Bemax's heavy mineral sand mining in the southwest region of WA continued at **Gwindinup**, about 30km 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 will further extend the mine life of the project. Bemax is planning to begin development of the Gwindinup South/Happy Valley South deposits at end of 2010. Heavy mineral production from Bemax's operations in the region in 2009 amounted to 115 478 tonnes of sulphate and secondary ilmenite and leucoxene as well as 13 983 tonnes of zircon.

Australian Zircon NL reported that its **Mindarie** zircon mine in the western Murray Basin, 148km east-north-east of Adelaide, SA, produced 798 tonnes of ilmenite, 2380 tonnes of rutile and 9553 tonnes of zircon in 2009. 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. In October 2009 the company reported that it had placed its Mindarie operation on care and maintenance.

In 2009, Austpac Resources NL reported that it had demonstrated that a process to significantly reduce the silica content of synrutile could be integrated in its Enhanced Roasting and Magnetic Separation Synthetic Rutile (ERMS SR) process. A large pilot scale facility to further investigate this new process was constructed during the quarter and was used to process Murray Basin ilmenite to further improve the high grade product produced by the ERMS SR demonstration plant in 2008 before undertaking further third party testwork.

Gunson Resources Ltd released a definitive feasibility study on its **Coburn** heavy mineral sand deposits in WA in January 2010. The study considered a mine life of 23.5 years with annual production rates of 40 000 tonnes of zircon, 90 000 tonnes of ilmenite, 9000 tonnes of rutile and 7000 tonnes of leucoxene. The company is currently seeking development funding and offtake partners.

Image Resources NL holds heavy mineral sand resources in north Perth Basin and in Eucla Basin, WA. Image carried out extensive drilling programs in north Perth Basin to upgrade the Indicated Resource of its **Atlas** deposit to a status of Measured Resources. The company also identified 16km long zone south of the Gin Gin townsite with drill intersections recording 6–40% heavy mineral content. In Eucla Basin the company reported an initial Indicated and Inferred Resource for its **Cyclone Extended** deposit of 148Mt at 1.5% heavy minerals containing 445 000 tonnes of zircon, and 188 000 tonnes of rutile + leucoxene.

In March 2010, Diatreme Resources Ltd released a scoping study on its **Cyclone** heavy minerals deposit in the Eucla Basin which indicated potential for a profitable mine producing about 280,000 tonnes of concentrate annually mining ore at a rate of 9 million tonnes per annum (Mtpa). In October 2010, the company reported an updated Measured, Indicated and Inferred Resource for the Cyclone heavy mineral sand deposit amounting to 132.1Mt at 2.33% heavy minerals, containing 3.1Mt heavy minerals. The new resource contains 998 000 tonnes of zircon, 388 000 tonnes of rutile, 551 000 tonnes of Hiti (70–95% TiO₂), and 382 000 tonnes of altered ilmenite (55–70% TiO₂).

The Cyclone Extended deposit forms a southeast extension of the Cyclone deposit. In September 2010, Image Resources NL and Diatreme Resources Ltd signed a memorandum of understanding to cooperate in advancing the development of both the Cyclone and Cyclone Extended deposits.

Astron Ltd's **Donald** project in the Murray Basin in Vic comprises the Donald (WIM 250) and Jackson (WIM 200) heavy mineral sand deposits is located 240km west-north-west of Melbourne. In April 2010 the company announced an Indicated and Inferred Resource for the deposits of 2100Mt at 1.1% zircon, 2% ilmenite, 0.1% rutile and 0.9% leucoxene. A Probable Reserve within this resource was announced in July 2010 amounting to 305Mt at 6.3% heavy minerals, which equates to 19.215Mt of heavy minerals at 19% zircon, 32% ilmenite, 19% leucoxene and 4.4% rutile. The project is planned to be a 7.5Mtpa mining operation, producing 500 000tpa of heavy mineral concentrate for export to China. On 17 March 2009, a wholly owned subsidiary of Astron Ltd, DMS Pty Ltd, reported that it had received provisional Australian Government approval under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC1999) to commence mining the Donald heavy mineral sands deposit and a mining licence was granted by the Department of Primary Industries, Vic.

In October 2008, Matilda Minerals Ltd, the previous owner of the **Tiwi Islands** mineral sands mine in the NT, entered 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. Mining was recommenced in June 2010 and the company plans to produce 40 000 tonnes of zircon and rutile concentrates.

Molybdenum

Roy Towner (roy.towner@ga.gov.au)

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 also recovered as a by-product or co-product of copper and tungsten mining.

Resources

Australia's Economic Demonstrated Resources (EDR) of molybdenum rose from 225 kilotonne (kt) in 2008 to 276kt in 2009. All the increase occurred at Ivanhoe Australia Ltd's Merlin deposit in northwest Queensland (Qld). Western Australia (WA) has Australia's largest molybdenum EDR with about 79%, followed by Qld with 19% with the remainder in the Northern Territory (NT) and New South Wales (NSW).

Subeconomic Demonstrated Resources (SDR) account for about 77% of the total Demonstrated Resources with Qld accounting for 91% of SDR followed by WA with 9%.

In 2009, the Paramarginal Resources increased about 9-fold to 904kt, while the Submarginal Resources decreased from 260kt to 5kt because of resource assessment.

Inferred Resources decreased by 60% to 263kt in 2009 because non-compliant pre-Joint Ore Reserve Committee (JORC) Code resources were removed from the national inventory. WA and Qld account for 61% and 36% of Inferred Resources respectively.

Accessible EDR

All of Australia's EDR of molybdenum is accessible.

JORC Reserves

JORC Code reserves comprise total molybdenum in Proved and Probable Ore Reserves as defined in the JORC Code. In 2009, JORC Code reserves of 220kt accounted for approximately 80% of Accessible Economic Demonstrated Resources (AEDR).

Exploration

The rise in prices for molybdenum in the period 2007–08 led to an increase in molybdenum exploration, which has resulted in upgrades of resources at several deposits. Data relating to exploration expenditure for molybdenum are not available nationally.

Ivanhoe Australia Ltd reported that resources for the **Merlin** molybdenum-rhenium (Re) deposit, in northwest Qld, at a cut-off grade of 0.3% Mo were: Indicated Resources of 5.2 million tonnes (Mt) at 1.0% Mo, 16 grams/tonne (g/t) Re, 0.2% copper (Cu), 4g/t silver (Ag) for a contained 52 000 tonnes Mo and 83 000 kilogram (kg) Re, and Inferred Resource of 3.5Mt at 0.8% Mo, 14g/t Re, 0.3% Cu, 4g/t Ag for a contained 28 000 tonnes Mo and 49 000kg Re. The company announced that further drilling on its Cloncurry tenements resulted in additional high-grade intersections. In the southern area of Merlin, high-grade mineralisation at **Little Wizard** was identified with intersections of 1.4 metres (m) grading 9.3% Mo, 103g/t Re; 1.8m grading 12.9% Mo, 178g/t Re, and 4.3m grading 15.0% Mo, 188g/t Re. The company reported an Inferred Resource for Little Wizard of 15 000 tonnes grading 13% Mo, 160g/t Re, 1.7% Cu and 0.8g/t gold (Au).

Drilling at **Lanham's Shaft**, north northeast of Merlin, by Ivanhoe Australia Ltd discovered high-grade molybdenite hosted in calc-silicates and carbonaceous metapelites. Intersections reported included: 4m grading 8.5% Mo and 14.3g/t Re; 11m grading 0.12% Mo and 0.40g/t Re, and 9m grading 0.31% Mo and 5.32g/t Re.

Aussie Q Resource Ltd announced an initial resource for the **Gordons** molybdenum-copper prospect of 3Mt grading 0.051% Mo, 0.07% Cu and 1g/t Ag. Gordons is part of the **Whitewash** molybdenum-copper project, near Monto, Qld, which has a total resource of 71.5Mt grading 0.034% Mo, 0.1% Cu and 1.2g/t Ag containing more than 24 000 tonnes of Mo, more than 70 000 tonnes of Cu and 2.6 million ounces of Ag. Drilling at **Whitewash South** returned significant intersections including 39m grading 232 parts per million (ppm) Mo, 0.23% Cu and 2.6g/t Ag, and 78m grading 0.2% Cu, 157ppm Mo and 2.0g/t Ag.

Zamia Metals Limited reported a JORC Code compliant Inferred Resources of 130Mt grading 0.04% Mo at a cut-off grade of 200ppm Mo for its **Anthony** molybdenum deposit, north of Clermont, Qld. The deposit is a porphyry Mo system in which the molybdenite occurs in veins cutting altered igneous rocks and the surrounding schists. The deposit is oxidised to a depth of 60 to 80m.

Production

There was no molybdenum production in Australia in 2009.

World Ranking

In 2009, world economic resources are estimated to be about 8700kt, based on the United States Geological Survey (USGS) data, with China, the USA, and Chile holding about 82% of the resources.

The USGS estimates that world molybdenum production in 2009 amounted to 200kt compared with 218kt in 2008. China, the USA, Chile and Peru accounted for about 87% of global outputs in 2009 with China producing 77kt, followed by the USA with 50kt, Chile with 32kt and Peru with 15kt.

Industry Developments

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. However, the price declined sharply to US\$8/lb from late October 2008 and it continued at that level through the first half 2009. From second half 2009 to the end of first half 2010, the average price has fluctuated around US\$15/lb.

Metallic Minerals Limited's **Wolfram Camp** tungsten-molybdenum project 90 kilometres (km) west of Cairns in Qld has been under care and maintenance since late 2008. Drilling in late 2009–early 2010 provided a revised resource estimate for the project of 1.42Mt grading 0.6% tungsten oxide (WO₃) and 0.12% Mo. This comprises 0.78Mt grading 0.56% WO₃ and 0.13% Mo in the Indicated Resource category and 0.64Mt grading 0.65% WO₃ and 0.11% Mo in the Inferred Resource category. The company's 76% owned-subsiary, Planet Metals Limited, has commenced investigations to enhance the run of mine pre-concentrate in order to improve the mill-feed grade.

Moly Mines Ltd has commenced a final engineering works feasibility study on its **Spinifex Ridge** project in the Pilbara region of WA. The project comprises a 10 million tonnes per annum (Mtpa) operation utilising an ore head grade of 0.07% Mo and 0.11% Cu, at a proposed capital set-up costs of between \$528 and \$558 million. Native Title, environmental and other mining approvals which the company received for its original 20Mtpa project are suitable for the revised 10Mtpa project with some minimal changes required. The project has a combined Proved and Probable Reserves of 451Mt grading 0.05% Mo, 0.08% Cu and 1.3g/t Ag.

Thor Mining PLC has reported total Proved and Probable Reserves of 2.21Mt grading 0.47% WO₃ and 0.21% MoS₂ for its **Molyhil** tungsten-molybdenum project, 250km northeast of Alice Spring in the NT. The company has an off-take agreement with CITIC Australia Trading Limited, one of China's largest state-owned companies, which commits CITIC to take all of the molybdenum and tungsten concentrates produced from the project. In line with the reduction of international prices for molybdenum, the company has scaled back activities and placed the Molyhil development on hold.

Ivanhoe Australia Ltd released the results of its Scoping Study on the **Merlin** deposit near Cloncurry in northwest Qld, which indicated that, for an initial 9-year mine-life operation, the project could produce about 5300 tonnes per annum (tpa) of Mo and 7.5tpa of Re for an initial capital cost of \$319 million. The study also indicated that the average life-of-mine operating cash costs, including by-product credits, would be US\$3.16/lb of Mo. As a consequent of the positive Scoping Study, the company plans to complete a prefeasibility study by the end of 2010. The Merlin deposit, has a resource of 16Mt grading 0.6% Mo, 10g/t Re, 0.2% Cu and 3g/t Ag.

D'Aguilar Gold Limited's **Anduramba** molybdenum project, 150km west of Brisbane, Qld, contains a JORC Code compliant Indicated Resource of 21Mt grading 567ppm Mo, 5.68ppm Ag and 159ppm Cu, and an Inferred Resource of 10.6Mt grading 488ppm Mo, 2.81ppm Ag and 94ppm Cu. The company's proposed detailed feasibility study for the project was placed on hold following the onset of the global financial crisis and subsequent dramatic fall in metal prices in late 2008. However, with the improving metal price in the early 2010 the company has started reassessing the project.

Nickel

Yanis Miezitis (yanis.miezitis@ga.gov.au)

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 decreased by 9.1% from 26.4 million tonnes (Mt) to 24.0Mt in 2009. About 83% of Australia's EDR is held in 15 deposits. Australia's EDR of nickel can be subdivided as follows:

- About 20% of Australia's EDR comprise Reserves as defined under the Joint Ore Reserve Committee (JORC) Code.
- About 32% is made up of published JORC Code compliant Measured and Indicated Resources in operating mines, in deposits being developed for mining and in deposits which have published scoping/feasibility studies with positive results.
- The remaining 48% of Australia's EDR of nickel are in deposits with Measured and Indicated Resources of similar tonnage, grade, and ore type being mined elsewhere in Australia, however a scoping/feasibility study has not been completed to date.

Western Australia (WA) remains the largest holder of nickel resources with 90.9% of total Australian EDR. New South Wales (NSW) is the second largest with 5.2%, followed by Queensland (Qld) with 3.5% and Tasmania (Tas) with 0.4%. 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 9.9% of total Identified Resources, increased from 4.3% during 2009. The Paramarginal Resources increased from 1.1Mt to 3Mt, while the Submarginal Resources increased from 1Mt to 1.9Mt in 2009. WA has 69.4% of the subeconomic nickel resources.

Inferred Resources increased from 20.9Mt to 21.2Mt in 2009. WA maintained its dominant share of Australia's Inferred Resources with 89.6% followed by Qld with 5.9%.

The ratio of Inferred Resources to EDR in 2009 was 0.88:1.

Accessible EDR

Currently, all nickel EDR is accessible for mining. At the rate of production in 2009, Accessible Economic Demonstrated Resources (AEDR) of nickel are sufficient for about 145 years.

JORC Reserves

About 20% of AEDR comprise Joint Ore Reserve Committee (JORC) Code reserve. The remaining 80% of EDR 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.

Total JORC Code reserves of nickel are adequate for 28 years at current rates of production.

Exploration

Expenditure on nickel-cobalt exploration for 2009 as reported by the Australian Bureau of Statistics (ABS), was \$186.3 million, a decrease of 42.5% on 2008. WA attracted most of this expenditure with \$176.8 million. Other States with significant nickel-cobalt exploration included Qld, SA, NSW and Tas.

Production

All of Australia's nickel production in 2009 was from WA and amounted to 165 kilotonnes (kt) which was down from 200kt in 2008, as reported by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES). The value of all nickel products exported was \$3.226 billion. Australia was the world's fourth-largest producer, accounting for 11.6% of estimated world mine production of nickel.

World Ranking

Based on figures published by the United States Geological Survey (USGS) and the latest Australian resource figures, world economic resources of nickel decreased to 68.6Mt in 2009 from 69.9Mt in 2008. Australia's share of world economic resources of nickel was 35% in 2009. It remained the largest holder of economic resources followed by New Caledonia (10.3%), Russia (9.6%) and Cuba (8.0%).

Russia was the largest producer with 266kt (18.6%), followed by Indonesia with 189kt (13.3%), Canada 181kt (12.7%) and Australia with 165kt (11.6%).

Industry Developments

Falling nickel prices and reduced demand in the aftermath of the global financial crisis in late 2008 led to mine closures and significantly reduced nickel production. During 2009 the nickel price recovered from an average of US\$4.94 a pound (lb) Ni for the quarter ending 31 December 2008 to US\$7.95/lb Ni for the quarter ending 31 December 2009. During the June quarter of 2010 the average nickel price reached US\$10.15/lb Ni. The major sulphide nickel mines, owned by BHP Billiton's Nickel West, continued operating at Leinster, Mount Keith and Cliffs north of Kalgoorlie, WA. A number of smaller sulphide nickel operations also continued to be operated 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 three of its sulphide nickel operations in 2009 and another two sulphide and one lateritic nickel operations were placed on care and maintenance. BHP Billiton's large and recently commissioned lateritic nickel operation at Ravensthorpe also was suspended in January 2009. In February 2010, BHP Billiton sold its Ravensthorpe operation to First Quantum Minerals Australia Nickel Pty Ltd which announced in October 2010 that it was planning to recommission the mine in the second half of 2011.

Nickel sulphide deposits

BHP Billiton's has reported that, its West Australian operations produced 113 400 tonnes of nickel during 2009 with most sourced from the Mount Keith, Leinster and Cliffs mines. Production was up from 85 900 tonnes in 2008, to reach record levels after a rebuild of the Kalgoorlie nickel smelter furnace was completed.

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 66% Ni. The mill and concentrator at Kambalda are supplied with third party ore and produce concentrate containing about 13% Ni. About 30–40% of the nickel matte was sold to overseas customers, but most 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 65 000 tonnes per annum (tpa) of nickel metal. BHP Billiton reported that a new hydrogen plant is being built at its Kwinana refinery and is expected to be completed in 2012.

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

BHP Billiton's Yabulu refinery produced 18 100 tonnes of nickel and 700 tonnes of cobalt in 2009. BHP Billiton sold the facility in July 2009.

According to the information provided in Norilsk Nickel's annual report for 2009, the Lake Johnston operations of Emily Ann and Maggie Hays mines (WA) produced 1367 tonnes Ni, and the Black Swan mine, also in WA, produced 2301 tonnes. Norilsk announced on 16 February 2009 that operations at Black Swan and the Johnston operations were suspended which followed suspension of the company's Waterloo mine in November 2008. Norilsk Nickel noted in its annual report for 2009 that optimisation of the Lake Johnston and Black Swan operations was



Surface facilities at Savannah nickel mine, Western Australia (Panoramic Resources Ltd)

in progress. It also reported that exploration expenditure in Australia in 2009 was minimal and was spent mainly on geophysical and geochemical surveys in Lake Johnston area, drilling and geophysical work on Honeymoon Well. The company reported that its capital investments in Australia in 2009 amounted to US\$4 million of which US\$1 million was spent on purchasing equipment for Norilsk Process Technology and US\$3 million was spent on maintenance of the Black Swan and Johnston mines.

Xstrata announced in its 2009 Annual Report that metal in concentrates produced from the Cosmos operation (WA), which includes the mines at Alec Mairs, Tapinos and Prospero, and the Sinclair mine reached a record of 16 678 tonnes Ni. Total ore milled in the period increased by 54% to 347 665 tonnes, mainly as a result of mining of the Prospero deposit. Xstrata reported that a low-cost expansion of the Cosmos mill was completed in 2009 which increased annual capacity to 13 500 tonnes of nickel in concentrate at lower unit costs. Development of the Prospero deposit continued throughout 2009, contributing to a 54% increase in production at Cosmos. The open pit mine at Sinclair was completed in the third quarter of 2009 while development of the underground mine was deferred in April 2009 due to market conditions.

Western Areas NL nickel mine at the Flying Fox deposit in WA produced 8097 tonnes of Ni in concentrate in 2009. Western Areas reported that by the end of 2009 mine development at Flying Fox had reached the top of the T5 orebody where a record drill hole intersection of 78 metres (m) at 9.3% Ni was recorded within the orebody. The main decline at the Flying Fox Mine reached 910m below surface. At the end of 2009 the nickel orebodies at the Flying Fox mine totalled about 107 000 tonnes of Ni metal. Mine production at the King Pit at Spotted Quoll deposit commenced in the first quarter of 2010 where the open pit contains 19 000 tonnes of Ni metal at 5.1% Ni and the underground resource totals a further 125 000 tonnes of Ni metal at 6.2% Ni. All ore mined at Spotted Quoll will be treated at the Cosmic Boy concentrator which was upgraded during the first half of 2010 to a capacity of 550 000tpa. The nickel concentrate from the Cosmic Boy plant is delivered under off-take contracts to BHP Billiton in Kalgoorlie and to the Jichuan Group in China.

During 2009, Panoramic Resources Ltd's underground mine operation at Savannah in WA produced 7957 tonnes Ni, 4437 tonnes Cu, and 420 tonnes Co. The Copernicus joint venture mining operation between Panoramic (60%) and Thundelara Exploration Ltd (40%) was suspended in January 2009 but stockpiled ore was processed through the Savannah mill. Nickel concentrates produced at the Savannah plant are contracted for sale to the Jinchuan Group in China. Panoramic acquired the remaining 25% interest in the Lanfranchi mine from its joint

venture partner Brilliant Mining Corp in May 2009. In 2009 Lanfranchi (WA) produced 10 161 tonnes of Ni and 794 tonnes of Cu. Most of the Lanfranchi production is derived from the Deacon orebody, while mining of the small high-grade Winner orebody was completed in September 2009. The ore from the Lanfranchi operation is processed at the Kambalda nickel concentrator owned by BHP Billiton.

Mincor Resources NL nickel production for 2009 was reported under two groups of operations in WA, the North Kambalda operation made up mainly of the Otter Juan and Carnilya Hill mines and the Coronet and McMahon operations. The two operations yielded a combined production in 2009 of 7509 tonnes of Ni, 502 tonnes of Cu and 91 tonnes of Co. The Southern Kambalda operations produced 4894 tonnes of Ni, 448 tonnes Cu and 91 tonnes Co, almost entirely from the Mariners operation, as well as the Redross mine which closed in May 2009. Drilling in the vicinity of the operating mines delineated possible new ore bodies below Mariners, the 'N11' mineralised zone and in vicinity of South Miitel which Mincor reopened in mid 2010.

Independence Group NL reported total production for 2009 of 8139 tonnes Ni and 618 tonnes Cu from its Long, Victor South and McLeay mines (WA). The first ore was mined in the first quarter of 2010 from the newly delineated Moran deposit.

Fox Resources Ltd is conducting metallurgical testing for a possible heap leaching operation to treat nickel and copper resources from the Radio Hill mine and the nearby Sholl deposit in WA. In mid 2010 the company announced updated Indicated and Inferred Resources of 4.22Mt at 0.65% Ni and 0.76% Cu for its Radio Hill mine. An Indicated and Inferred Resource of 5.78Mt at 0.54% Ni and 0.67% Cu was also reported for the Sholl B2 deposit.

In December 2008, OZ Minerals Limited suspended the Avebury mine in Tas as a consequence of prevailing low nickel prices. About 793 tonnes of Ni was produced from stockpiled ore during the March quarter of 2009 before the mine was placed on care and maintenance and sold to China Minmetals Corporation in mid 2009. China Minmetals Non-ferrous Metals has conditionally agreed to sell a portfolio of international mining assets to Minmetals Resources for US\$1.846 billion. The sale includes four operating mines, Sepon in Laos and Century, Golden Grove and Rosebury in Australia, and several other development properties, including the closed Avebury nickel mine.

Lateritic nickel deposits

The annual production for 2009 from the Murrin Murrin lateritic nickel plant in WA operated by Minara Resources Ltd reached record levels of 32 977 tonnes Ni and 2350 tonnes Co. The company reported that it is conducting scoping studies on the viability of processing ore from the Mount Margaret-Marshall Pool lateritic nickel deposits as a feed for the Murrin Murrin operation.

First Quantum Minerals Australia Nickel Pty Ltd acquired the Ravensthorpe lateritic nickel operation in WA from BHP Billiton in February 2010 and is refurbishing the mine plant with a planned restart of production in late 2011. First Quantum Minerals is planning to produce 39 000tpa of nickel metal for the first five years and 28 000tpa for the remainder mine life of about 30 years (Prospect Magazine. September-November 2010 Issue, Geological Survey Western Australia).

OJSC MMC Norilsk Nickel stated in its 2009 annual report that an optimisation of the facility operation and geological exploration at Cawse in WA was in progress.

The previous partner in Heron Resources Ltd's Kalgoorlie Nickel Project (KNP) in WA withdrew from the project in July 2009 after spending \$34.5 million on feasibility studies. 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 000tpa 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 nickel and cobalt extractions of 96% Ni and 93% Co. Cash operating cost was estimated to be US\$4.42/lb of nickel (including cobalt credits) and the capital cost was estimated to be US\$1.5 billion. Heron completed further metallurgical studies and a detailed mining study which looked at optimising individual pits and mining sequence. This study evaluated the project performance over three production rate scenarios of 2.5Mt (Vale Base Case), 3.75Mt and 5Mt a year of leach feed. The 3.75Mtpa leach feed scale is preferred because it provides the best project performance. 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 in China for this work.

During 2009, Metallica Minerals Ltd acquired the Greenvale and Lucknow nickel/cobalt lateritic nickel deposits in Qld which were added to the existing resources of the NORNICCO group of lateritic deposits, including Minnamoolka, Bell Creek and the Kokomo deposits. The new combined NORNICCO Measured, Indicated and Inferred Resource amounts to 76.31Mt at 0.80% Ni and 0.06% Co. At the end of 2009, Metallica completed an internal scoping study/pre-feasibility study which estimated an operating expense (OPEX) of \$US4.17/lb Ni produced, and \$US2.85/lb Ni after Co credits. In view of the high capital expense (CAPEX) of \$620 million and unfavourable financial climate at the time, Metallica repeated the feasibility study on a smaller processing operation (NORNICCO stage 1) which was based on the Greenvale mine site using selected high grade Ni and Co (>1.6% Ni equivalent) feed sourced from the Greenvale deposit and blended with cobalt rich Kokomo nickel laterite ores. The scoping study on the downsized project estimated total Stage 1 capital cost of \$132 million with operating costs in the order of US\$6.20/lb Ni or US\$5.10/lb Ni with Co credits or <US\$3/lb Ni after Co and scandium (Sc) credits. Estimated annual production for this operation is 2700 tonnes Ni, 160 tonnes of Co and 7500 kilograms of Sc.

Metals X completed the first phase of a feasibility study for the Wingellina lateritic nickel deposit (WA) in mid-2008 and confirmed a project concept for the construction of a nickel and cobalt operation producing approximately 40 000tpa Ni and 3500tpa Co with an initial mine life of 40 years at an operating costs of less than US\$3.50/lb of Ni after Co 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 \$3.4 billion. In July 2010 Metals X signed a Mining Agreement with the Ngaanyatjarra Land Council for the Wingellina project which is subject to regulatory approvals and a mining lease being granted.

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 although in mid 2009 the company reported that the global financial crisis may result in significant delays for the project. In August 2010 Gladstone Pacific announced that it had received a takeover proposal from Queensland Nickel Resources Pty Ltd.

Niobium

Leesa Carson (leesa.carson@ga.gov.au)

Roy Towner (roy.towner@ga.gov.au)

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

Resources

Australia's Economic Demonstrated Resources (EDR) of niobium was 115 kilotonnes (kt) in 2009 which was unchanged from 2008. The bulk of the EDR of niobium is associated with the Toongi deposit 20 kilometres south of Dubbo in New South Wales (NSW). This deposit is a sub-volcanic intrusive trachyte body (vertical) with dimensions of approximately 900 metres (m) by 600m, which has been drilled out to a depth of 55m to provide a Measured Resource of 35.7 million tonnes (Mt) grading 0.46% Nb₂O₅, and between 55m to 100m for an Inferred Resource of 37.5Mt grading 0.46% Nb₂O₅.

Paramarginal Resources totalling 15kt accounts for all the Subeconomic Demonstrated Resources and occur in the Mount Weld carbonatite deposit in Western Australia (WA).

Inferred Resources are estimated to be 543kt (811kt in 2008). WA is the largest holder of Inferred Resources with 78% associated with the Mount Weld deposit, and NSW holds the remaining 22% occurring in the Toongi deposit.

Accessible EDR

All of Australia's EDR of niobium is accessible.

JORC Reserves

Joint Ore Reserve Committee (JORC) Code reserves comprise total niobium in Proved and Probable Ore Reserves as defined in the JORC Code. In 2009, there were no reserves of niobium reported under the JORC Code.

Exploration

Exploration for niobium is occurring in WA and NSW, but there are no statistics available on exploration expenditure for niobium.

Production

Currently there is no production of niobium in Australia. However, in previous years niobium concentrates were recovered as a by-product of tantalum mining. According to the United States Geological Survey (USGS) Australia has been one of the leading suppliers of niobium in ores and concentrates into the USA which in 2008 amounted to 73% of the total imports of niobium in ores and concentrates.

World Ranking

Based on incomplete world estimates published by the USGS for 2009, the world's largest niobium resources, totalling 2900kt, are located in Brazil. Australia with 115kt has the world's second largest resources and Canada has 46kt. Based on USGS figures, world production of niobium in 2009 amounted to 62kt dominated by Brazil with 57kt and Canada with 4kt.

Industry Developments

Historically, Talison Minerals' **Greenbushes** mine, WA, produced tantalite-columbite concentrate for export. Columbite $\text{Fe}(\text{Nb},\text{Ta})_2\text{O}_6$ is the main niobium ore mineral. However, since 2008, the primary tantalum plant at Greenbushes has been under care and maintenance. Its secondary processing plant treats primary tantalum concentrates from the **Wodgina** mine, WA, where production as reported by the Western Australian Department of Mines totalled 105kt of tantalite in 2009, down from 680kt in 2008.

Alkane Resources Ltd demonstration pilot plant at ANSTO Minerals at Lucas Heights in Sydney, NSW, has been processing an initial 100 tonnes of ore from the **Toongi** deposit (referred to as the Dubbo Zirconia project) since 2008 and to date has recovered 1300 kilograms (kg) of zirconium chemicals and nearly 300kg of saleable niobium concentrate containing approximately 70% Nb_2O_5 . The demonstration plant also has produced zirconia concentrate and yttrium-rare-earth concentrate from the deposit. A development decision for the project is expected to be made by the company in late 2010, with production possible in 2012.

Phosphate

Leesa Carson (leesa.carson@ga.gov.au)

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) southeast 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 which is exported to the Asia-Pacific region with products used widely in the palm oil sector of the region. Higher-grade rock phosphate is used by 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, and horticultural 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, Australia's total Economic Demonstrated Resources (EDR) of phosphate rock in 2009 was 248.6 million tonnes (Mt), compared with 81.6Mt in 2008. Australia's EDR occur in sedimentary phosphate rock (phosphorites) at Phosphate Hill (Qld) which has an average grade of about 24% P₂O₅, and Wonarah in the Northern Territory (NT) which has an average grade of about 21.3% P₂O₅.

There is no publicly available information on phosphate rock resources for Christmas Island.

About 67% of Australia's total demonstrated resources of 1263Mt occur in the Georgina Basin in Qld and NT and are classified as Paramarginal. The remaining 33% of demonstrated resources occur in Western Australia (WA) within carbonatite at Mount Weld, 26km southeast of Laverton, at Balla Balla magnetite deposit 100km west-southwest of Port Hedland, and in the NT at Nolans Bore, 135km northwest of Alice Springs.

About 79% Australia's inferred phosphate resources, which total 1295Mt, occur as phosphorites in the Georgina Basin. These resources are distributed between Qld and the NT. The remaining 21% occur in WA mainly associated with the Mount Weld deposit.

Accessible EDR

All of Australia's EDR of phosphate is accessible.

JORC Reserves

Joint Ore Reserve Committee (JORC) Code reserves comprise total phosphate in Proved and Probable Ore Reserves as defined in the JORC Code. In 2009, JORC Code reserves of 81.6 kilotonnes (kt) accounted for approximately 33% of Accessible Economic Demonstrated Resources (AEDR).

Exploration

Although specific data on phosphate rock exploration expenditure are not reported by the Australian Bureau of Statistics, there has been an increase in company exploration for phosphate, particularly in Qld and the NT, as a consequence of increased world demand for the fertilizers.

Phosphate Australia Ltd announced results from drilling at its **Highland Plains** project 500km east of Tennant Creek, NT. Drill intersections included: 10 metres (m) grading 24.7% P₂O₅ from 8m, including 4m grading 31.1% P₂O₅, and 5m grading 24.7% P₂O₅ from 34m. The company also reported an increased resource of 14Mt grading 20% P₂O₅ at the Western Mine Target Zone in the project.

Minemakers Ltd announced an updated resource for the **Wonarah** deposit, 200km east of Tennant Creek, to an Indicated and Inferred Resource of 1105Mt at average grade of 18% P₂O₅. At a 15% P₂O₅ cut-off, the resource is 399Mt grading 21% P₂O₅. Minemakers announced plans to bring the project into production in 2010.

Krucible Metals Ltd announced a revised Inferred Resource for **PHM South**, 150km southeast of Mount Isa and 5km south of the Phosphate Hill Mine, Qld. At a cut-off grade of 10% P₂O₅, the Inferred Resource is 19.3Mt grading 19.0% P₂O₅. The company is undertaking a scoping study to ascertain a range of economic parameters for mining and aims to produce up to 3.6Mt at about 32% P₂O₅ over six years at an annual rate of 0.6Mt.

Mount Isa Metals Ltd announced an Inferred Resource of 135Mt grading 13.8% P₂O₅ (at a cut-off grade of 10% P₂O₅) for the D-Tree deposit, Qld. The D-Tree Project is a joint venture between Mount Isa Metals (20%) and Legend International Holdings Inc (80%, manager). Elsewhere in the project area, at D-Tree West the resource is

170Mt grading 16.0% P₂O₅. An Inferred Resource of D-Tree Direct Shipping Ore, at a 25% P₂O₅ cut-off, was reported as 1Mt grading 29.4% P₂O₅ and is in the high-grade portion of D-Tree North.

Production

There are two main locations for the production of phosphate rock, Phosphate Hill (Qld) and Christmas Island.

The Queensland Department of Mines and Energy estimates that Incitec Pivot's production from Phosphate Hill in 2008–09 amounted to 1.958Mt of phosphate rock (compared with 2.154Mt in 2007–08). Phosphate Resources Ltd's production figures for its Christmas Island operation in 2009 are not available because of commercial-in-confidence considerations. However, the company shipped 563 000 tonnes in 2008–09.

Several small operations near Bendleby in South Australia produced about 5670 tonnes of phosphate rock in 2009, which is used mainly in domestic industrial applications.

World Ranking

The United States Geological Survey (USGS) estimated that total world resources of phosphate rock are 16 000Mt. Australia's EDR comprises less than 2% of the world's resources. Morocco and Western Sahara (combined) hold about 36%, followed by China with 23%, Jordan and South Africa each with 9% and the USA with 7%.

The USGS estimated that world production of phosphate rock totalled 158Mt in 2009 (161Mt in 2008), with China producing 55Mt, the USA 27.2Mt and Morocco and Western Sahara 24Mt. The USGS estimates that, excluding Christmas Island, Australia produced 2.5Mt in 2009.

Industry Developments

Phosphate rock prices rose strongly during 2008 reaching around US\$450 a tonne Free-on-Board (FOB) Morocco by mid year as a result of the increasing global demand for fertiliser for food production and for biofuel crops. However, the global financial crisis impacted strongly on phosphate demand and pricing. By early 2009 prices had retracted substantially to US\$110 a tonne, which is still significantly above the long term average price of US\$50. By early 2010, prices had risen to about US\$120 a tonne. The Chinese demand for phosphate grew by 18% in 2009 and is expected to continue, which is likely to result in China importing phosphate rock to supplement domestic production.

Legend International Holdings Inc. (Legend) completed a feasibility study on the **Paradise North** and **Paradise South** deposits, located about 70km north of Mount Isa. The study envisages a mining project commencing at Paradise North in 2013 with more than one million tonnes per annum (Mtpa) of phosphate rock mined, dry screened on site for the removal of silica to upgrade the ore to about 29.5% P₂O₅ before being trucked to a Phosphate Fertiliser Complex to be constructed at Mount Isa. In 2017, ore will be mined at the Paradise South deposit and processed through an on-site flotation beneficiation plant. About 1Mtpa of ore grading 32.5% P₂O₅ will be trucked to the Mount Isa Fertilizer Complex. The Mount Isa Complex will consist of a sulphuric acid plant, phosphoric acid plant, ammonium phosphate plant and an aluminium fluoride plant. The company estimates that the capital cost for the total project development will be US\$808 million, with combined production of MAP and DAP to be in the order of 600 000 tonnes a year. The company has reported that the combined resources of the Paradise North and South deposits is 81Mt grading 18.1% P₂O₅.

Legend is working in conjunction with Wengfu Group of China on a Feasibility Expansion Study (FES) to assess the feasibility of doubling production to 1.2Mtpa of DAP/MAP. The FES includes preliminary designs for a 1Mtpa, increasing to 2Mtpa, phosphate rock flotation beneficiation plant to be built at Paradise South.

Swift Venture Holdings Corporation, a Singapore-based investor, has acquired a 70% option over GBM Resources Ltd's phosphate resources at its **Bungalien** project, Qld, located 50km north of the Phosphate Hill deposit. Drilling at the project has returned phosphate values ranging from 10% to 22% P₂O₅.

Krucible Metals Ltd is carrying out a scoping study on the possibility of producing up to 600 000 tonnes per annum (tpa) of phosphate rock from its **Korella Phosphate** deposit, immediately south of Incitec Phosphate Hill deposit, Qld. The company reported an Inferred Resource of 8.3Mt grading at 27.3% P₂O₅ based on a cut-off grade of 20% P₂O₅.

Korab Resources Limited has completed its feasibility study on the rock phosphate deposit located at **GeolSec** near Rum Jungle, 65km south of Darwin in the NT. The study indicated that the deposit could be developed as a simple quarrying operation with no processing other than grinding and bagging. It would be capable of supplying the agricultural sector with a finely ground-up rock phosphate to be used as an organic fertiliser. The quarrying, transport and processing costs would be less than \$100/tonne. Subject to receiving the necessary government approvals and permits, the company is planning an initial production in early 2011 of 15ktpa increasing to 30ktpa by 2013. Start-up costs for the operation are in the order of \$300 000 to \$500 000.

Phosphate Australia Limited reported that metallurgical testwork on its **Highland Plains** phosphate project in the NT involving flotation and magnetic separation has produced a high quality rock phosphate grading up 35.6% P_2O_5 with a low combined contaminant value of 1.7% Fe_2O_3 plus Al_2O_3 . The company is progressing with its pre-feasibility studies on the Highlands Plains project where it has reported Inferred Resources of 56Mt at 16% P_2O_5 at a cut-off grade of 10%. Within this resource, the company has a higher grade zone, its Western Mine Target Zone, where resources have increased to 14Mt at 23% P_2O_5 at a cut-off grade of 15% P_2O_5 . The company is aiming for the production of up to 3Mtpa of beneficiated rock phosphate to be transported by a slurry pipeline to a barging facility in the Gulf of Carpentaria.

Minemakers Ltd has completed its direct shipping ore (DSO) feasibility study into its **Wonarah** phosphate project in the Georgina Basin in the NT. The project involves mining two deposits, known as Arruwurra and Main Zone. The project has JORC Code compliant Indicated Resource of 399Mt grading 21% P_2O_5 , based on a cut-off grade of 15% P_2O_5 . The company plans to develop a high-grade open cut mine producing DSO commencing at 0.5Mtpa and increasing to 3Mtpa over two and half years. The material will be transported through Tennant Creek to Darwin commencing in late 2011 early 2012. The cost of developing a 3Mtpa project would be about \$110 million.

Minemakers has lodged its Wonarah Environmental Impact Statement with the Northern Territory Government for consideration.

The company has made a minority investment into JDCPhosphate, a Florida company which has granted sole Australian licence to Minemakers for the use of JDC's patented dry kiln technology to produce super phosphoric acid. This process has relatively lower operating and capital costs than conventional wet technique for producing phosphoric acid. Minemakers has signed a non-binding Memorandum of Understanding also with the Verte Group Pty Ltd which will seek equity funding for the development of the Wonarah project. The equity funding will be for a DSO mine and transport start-up infrastructure and a large rock phosphate beneficiation plant at Wonarah as well as a 260km railway from Wonarah to the Adelaide to Darwin railway near Tennant Creek, a gas pipeline to Wonarah from Tennant Creek, a fertiliser and other phosphate chemical plants at Wonarah or Darwin, storage and related facilities at the port of Darwin and a transport hub facility near Tennant Creek, if required.

Arafura Resources Ltd reported that its **Nolans Bore** rare earth-phosphate-uranium-thorium deposit, located 135km northwest of Alice Springs in the NT has combined Measured, Indicated and Inferred Resources totalling 30.3Mt to a depth of 130m which grades at 2.8% rare earth oxide (REO), 12.9% P_2O_5 , 0.44 pounds per tonne U_3O_8 , and 0.27% Th. The company is conducting a definitive feasibility study on the project and, in July 2010, reported that it is on track to commence production in 2013.

Navigator Resources Limited updated the resources of its **Cummins Range** rare earth oxide-uranium-phosphate, 130km southwest of Halls Creek, WA. In September 2009, the project contained Inferred Resources of 4.17Mt at 1.72% total REO, 11.0% P_2O_5 , 187 parts per million (ppm) U_3O_8 and 41ppm Th at a cut-off grade of 1% total REO. The mineralisation is up to 50m thick and occurs in a sub-horizontal geometry within weathered regolith which is developed over carbonatite and pyroxenite rocks. A mineralogical investigation of the Cummins Range deposit by the CSIRO Minerals Down Under Flagship was completed during the March 2010 quarter with the principal rare earth bearing minerals being primary apatite and monazite and only subordinate amounts of secondary rare earth bearing minerals present.

Aurox Resources Limited is evaluating the potential for phosphate production from its **Balla Balla** project, WA. The project currently has a total phosphate resource of 89.69Mt grading 3.74% P_2O_5 . The phosphate, in the form of apatite, occurs in the waste rock in the hanging wall immediately above the titanomagnetite ore zone at Balla Balla. The phosphate would require beneficiation as most phosphate rock is commonly sold at a grade close to 30% P_2O_5 .

On Christmas Island, Phosphate Resources Ltd shipped 566 645 tonnes of phosphate during 2009–10 which compared with 563 000 tonnes during 2008–9. The company's current resource statement and lease term provide for a 2019 completion date for mining operations. On 16 July 2010, the Minister for the Environment rejected the company's new mining lease applications to explore and mine an additional eight areas comprising a total of 256 hectares on the grounds it would have an unacceptable impact on the environment.

Platinum Group Elements

Yanis Miezitis (yanis.miezitis@ga.gov.au)

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 platinum, palladium and, to a lesser degree, rhodium. 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 motor vehicle 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 (2010)², the main demand for platinum in 2009 was autocatalyst applications (32%) and jewellery manufacture (43%). The main demand for palladium was also in autocatalyst (52%) and jewellery production (10%).

Resources

Australia's Economic Demonstrated Resources (EDR) of PGEs decreased from 18.9 tonnes to 5.2 tonnes in 2009 as a result of reclassification of resources.

Western Australia (WA) and the Northern Territory (NT) hold all of Australia's resources of EDR. However the EDR of PGEs in individual deposits within State jurisdictions is often unrecorded so that the overall distribution of the PGE EDR is unknown.

In 2009, the Paramarginal Resources increased from 118.5 tonnes to 132.3 tonnes while the Submarginal Resources remained the same at 35.3 tonnes. The Paramarginal Resources are shared mostly between WA (88%) and New South Wales (NSW) (10%), while most of the Submarginal Resources are in WA.

Inferred Resources remained unchanged from 2009 at 145.3 tonnes. WA had most of these resources (86.6%), followed by NSW (11.0%) and NT (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, 0.9 tonnes of the published PGE EDR is accessible for mining while the balance of 4.3 tonnes occurs within national parks.

JORC Reserves

About 13% of Accessible Economic Demonstrated Resources (AEDR) of PGEs comprise Joint Ore Reserve Committee (JORC) Code reserve. The remaining 87% of EDR 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. The reason for the low reserve figure is that many companies don't report the PGE content in their nickel reserves.

² Matthey, J. 2010 Platinum 2010. Johnson Matthey Public Limited Company. Precious Metals Marketing. http://www.platinum.matthey.com/uploaded_files/Pt_2010/10completepublication.pdf

Exploration

Expenditure for PGEs is not reported separately and much of the PGE resources are associated with nickel deposits. Areas of activity in 2009 where PGEs were a significant component of exploration targets included the West Musgrave in the WA, NT and South Australian (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

Australia has made an insignificant contribution to the global PGE industry with all its PGE production (Pd and Pt) of ~726 kilograms (kg) in 2009 being a by-product of mining nickel sulphide deposits in WA (Source the Western Australia Department of Mines and Petroleum). This contribution had a value of \$7.5 million. In recent years, Australia produces annually about 300 to 850kg of palladium and 50 to 320kg of platinum. This production is exclusively from nickel sulphide deposits hosted by Archean komatiitic rocks in the Yilgarn Craton of WA.

World Ranking

Based on figures published by the United States Geological Survey and the latest Australian resource figures, world economic resources of PGEs was unchanged at 71 000 tonnes in 2009. Australia's share of world EDR was 0.01% in 2009. South Africa has most of the world's EDR with 63 000 tonnes (89%), followed by Russia with 6200 tonnes (9%), and the USA with 900 tonnes (1.3%).

The world's supply of PGEs in 2009 was dominated by South Africa (78% Pt, 35% Pd) and Russia (12% Pt, 50% Pd), with minor contributions from Canada, Zimbabwe, the USA and Colombia. Johnson Matthey (2010) stated that the global supply was 223.2 tonnes of palladium and 188.3 tonnes of platinum in 2009. Australia's annual production of palladium and platinum equates to about 0.2% of global supply.

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 its focus on a smaller project with scope for selective mining and on recent metallurgical advances suited for small-scale processing. The company reported further in May 2010 that it was planning to undertake a diamond drilling program to delineate zones of higher-grade mineralisation and re-estimate the resource.
- **Panton**, WA—14.3Mt 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 10.2Mt at 0.61g/t Pt, 2Mt at 0.18% cobalt (Co) and 0.35% Ni. Historical production from this deposit amounted to about 640kg of PGEs. The deposit is held by Platina Resources Limited and the company is currently drilling the Owendale deposit at Fifield and re-assaying some of the core from historic drill holes.
- **Weld Range—Parks Reef** PGE (with minor Au) deposit, WA—a published Inferred Resource amounted to 14.76Mt at 1.1g/t Pt+Pd+Au which occurs in a truncated lateritic profile overlying low-grade primary PGE mineralisation in ultramafic rocks³ The Weld Range PGE deposit is adjacent to the very large Weld Range lateritic nickel-cobalt deposit which has an Inferred Resource of 330Mt 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 the Weld Range tenements covering the lateritic nickel-cobalt deposit and the separate PGE dominant deposit. The Weld Range lateritic nickel-cobalt deposit has recently attracted attention as a chromium resource with a published Inferred Resource of 63.5Mt at 5.2% chromium (Cr), 38% iron and 0.38% Ni at a cut-off grade of 4% Cr. A scoping study was released by Weld Range Metals Ltd in August 2010 which concluded that Stage 1 of the project is technically and economically feasible using processing equipment and technology currently used by the steel industry. The company also stated it was planning to proceed with a definitive feasibility study.

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.

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 1.275Mt at 0.493g/t. Details are not available on production of palladium in 2009. In mid 2010 the company announced updated Indicated and Inferred Resources of 4.22Mt at 0.65% Ni and 0.76% Cu for its Radio Hill mine. An Indicated and Inferred Resource of 5.78Mt at 0.54% Ni and 0.67% Cu was reported also for the nearby Sholl B2 deposit but no details were given for palladium content. The mine is on care and maintenance while the company is investigating options for heap leaching nickel and copper.
- **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 16Mt at 0.87% Ni, 0.06% Co of which there is 3Mt at 290ppm scandium (Sc) and 0.22g/t Pt. The scandium-rich portion of this deposit was updated in June 2009 as Measured Resources of 2.718Mt at 274ppm Sc and Indicated Resources of 9.294Mt at 258ppm Sc.
- **The Horn** nickel sulphide deposit, WA—in April 2008, Breakaway Resources Limited reported a small Inferred Resource for its 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 had been drilled over a 500 metre strike length and remained open along strike. Geological mapping undertaken during the March quarter of 2009 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 2.9Mt at 0.79g/t PGE was announced by Washington Resources Ltd in March 2006.

Other PGE deposits with recorded resources which have had historic interest but did not record exploration or assessment activity in 2009 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 393Mt 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 108.3Mt 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 6.69Mt 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 10kg of Pt was extracted.

Potash

Yanis Miezitis (yanis.miezitis@ga.gov.au)

The term potash refers to potassic fertilisers, which are potassium chloride (KCl or sylvite), potassium sulphate [K_2SO_4 or sulphate of potash (SOP), which usually is a manufactured product], and potassium-magnesium sulphate [$K_2SO_4 \cdot 2MgSO_4$ or either langbeinite or double sulphate of potash magnesia (SOPM or K-Mag)]. Muriate of potash (MOP) is an agriculturally acceptable mix of KCl (95% pure or greater) and sodium chloride (halite) for fertilizer use, which includes minor amounts of other nontoxic minerals from the mined ore and is neither the crude ore sylvinitic nor pure sylvite.

Resources

Historically Australia has always been deficient in known resources of potash. For this reason Geoscience Australia has not compiled national scale resource information on potash because there has not been sufficient to record. Also, exploration has not been successful in locating commercially significant resources of potash.

In recent years however, sharp increases in the price of potash prior to the global financial crisis in late 2008 and the first half of 2009 encouraged exploration for potash in Australia and resources have been recently published for Lake Disappointment, Lake Chandler and Lake Mackay in Western Australia (WA).

JORC Reserves

Currently there are no Joint Ore Reserve Committee (JORC) Code reserves for potash resources.

Exploration

Interest in exploration for potash continued in 2009 in Lake Disappointment, Lake Mackay, south Carnarvon Basin and Canning Basin in WA as well as the Adavale Basin in Queensland (Qld) and in the Barrow Creek area in Northern Territory (NT).

Production

According to the United States Geological Survey (USGS), about 93% of the world potash production in 2009 was consumed by the fertilizer industry. Potassium chloride is the main fertilizer product, containing an average 61% of K_2O equivalent. In 2009, the main producers of potash were Canada with 6.5 million tonnes (Mt) followed by Belarus (3.85Mt) and Russia (3.6Mt). The three accounted for about 56% of the world production of 25Mt, which was down from 35Mt in 2008.

In Australia, some minor historic production of potash include an operation at Buladelah Mountain, New South Wales, where alunite $KAl_3(SO_4)_2(OH)_6$, was mined during 1890 to 1926 and again from 1935 to 1952, for a total production of 75 000 tonnes. Crude potash in form of soluble salt glaserite $(K,Na)_2SO_4$, was produced from Lake Chandler during 1943 to 1950 for a total of 9218 tonnes of glaserite.

In 1973, Geoscience Australia's predecessor, the Bureau of Mineral Resources, reported that Texada Mines Pty Ltd was working towards becoming Australia's first local potash producer in the form of langbeinite $K_2Mg_2(SO_4)_3$ at Lake Macleod, northwest WA. The planned capacity of the proposed plant was variously reported to be from 80 000 to 200 000 tonnes per annum (tpa). There is no record of production of potash from the proposed operation.

Australia imports all of its potash requirements and according to the Australian Bureau of Agriculture and Resource Economics and Sciences (ABARES) Australian Commodity Statistics 2009, the imports of potassium fertiliser amounted to 306 kilotonnes (kt) in 2006–07, 465kt in 2007–08 and 331kt in 2008–09 and was valued at \$85 million in 2006–07, \$165 million in 2007–08, and \$355 million in 2008–09. These trends confirm those reported by the USGS, which showed that although demand for potash decreased sharply during the global financial crisis, potash prices remained high.

World Ranking

According to the USGS the countries with the largest economic resources of potash (K_2O) were Canada 4.4 gigatonnes (Gt), which represents 51.8% of the total world resource, followed by Russia with 1.8Gt (21.2%) and Belarus with 0.75Gt (8.8%).

Industry Developments

Lake Disappointment: Located in the Gibson Desert of WA about 320 kilometres (km) east of Newman, Lake Disappointment is a modern playa lake covering approximating 1600 square kilometres. Potash mineralisation occurs in lacustrine sediments of the lake and in the entrained brine.

On 13 March 2007, Reward Minerals Ltd published a lower estimate of 7705Mt Indicated Resource at 3.17 kilograms/tonne (kg/t) K_2SO_4 containing 24Mt K_2SO_4 and an upper estimate of 8635Mt at 3.17kg/t K_2SO_4

containing 27.37Mt K_2SO_4 . The difference between the upper and lower figure is the result of assumptions about the depth and area for the lake margins.

This resource has been the subject of a dispute with the traditional land owners of the Lake Disappointment site and currently is inaccessible.

Lake Chandler: On 29 January 2009, ActivEX Limited announced a JORC Code compliant Inferred Resource of 5.779025Mt of ore at 5.73% K_2O at its Lake Chandler potash deposit situated 45km north of Merredin and 300km east of Perth in WA. The company reported in its 2010 annual report that it carried out a scoping study on a nominal throughput of 200 000tpa to give the project a mine life of 25 years. The company concluded that the study showed that, with the softness of the potash market, the project would be only marginal under the current economic conditions.

Lake Mackay: Situated in the Gibson Desert, straddling the WA-NT border 50km north of the Tropic of Capricorn Lake MacKay is a modern, playa lake with a surface area of more than 2250 square kilometres. Reward Minerals reported in its 2009 annual report that it has delineated a JORC Code compliant, Inferred Resource at Lake MacKay of 4 780 400 000 bench cubic metres (BCM) at 4.3kg of K_2SO_4 (SOP) per BCM for a total of 20.56Mt of K_2SO_4 .

The resource estimate was calculated on the basis of lakebed sediment volume of BCM to a depth of two metres and the water soluble potassium sulphate content of the sediments which lie within the company's tenement holdings.

The company reported that the next stage of development at Lake Mackay would involve the construction of pilot ponds and pump testing as well as flow sheet development for the compilation of a feasibility study. The company reported that the programs would depend on agreement with the traditional land owners.

Rare Earths

Yanis Miezitis (yanis.miezitis@ga.gov.au)

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 group of rare earth elements (REE) is variously, and inconsistently, reported by companies as light REE consisting of La, Ce, Pr, Nd and, sometimes, Sm. Heavy REE may start with Sm, followed by Eu through to Lu. However, the heavy REE are sometime subdivided further into middle REE comprising Sm, Eu, Gd, Tb and Dy with the remainder of the group, Ho to Lu, referred to as the heavy REE. Because of inconsistent reporting, the component elements of light, medium and heavy REE are best noted in each case. The resources of REE are usually reported as rare earth oxides (REO). Kingsnorth⁴ grouped La to Nd as light REE or 'Ceric', Sm to Gd as medium REE and Tb to Lu plus Y as heavy REE or 'Yttric'.

⁴ Kingsnorth, K., 2010. The challenges of meeting 'Energy' rare earths demand. IEA Standing Committee on Long-Term Co-operation Paris, 17th May 2010.

Table 3: Distribution of types of rare earth elements in selected deposits (Arafura Resources Ltd⁵)

Rare Earth Oxide	Application	Nolans Bore %	Mount Weld %	Mountain Pass USA %	Baiyunebo China %
Lanthanum	Petroleum cracking catalysts, batteries (NiMH)	19.74	25.6	33.2	27.1
Cerium	Autocatalyst, glass, polishing	47.53	45.74	49.1	49.86
Praseodymium	Magnets, glass	5.82	5.42	4.34	5.15
Neodymium	Magnets (NdFeB)	21.2	18.62	12.0	15.4
Samarium	Magnets, (SmCo)	2.37	2.44	0.8	1.15
Europium	Phosphors, nuclear control applications	0.4	0.55	0.12	0.19
Gadolinium	Intravenous contrast agents, phosphors	1.0	0.97	0.17	0.4
Terbium	Phosphors	0.08	0.09		
Dysprosium	Magnets (NdFeB), lasers	0.33	0.16		0.3
Other Rare Earths (Ho, Er, Tm, Yb, Lu)		0.21	0.04	0.16	0.03
Other elements					
Yttrium	Phosphors, metal alloys	1.32	0.37	0.1	0.2

The rare earths are a relatively abundant group of elements which range in crustal abundance from Ce, which is the 25th most abundant element at 60 parts per million (ppm), to Lu, the 61st most abundant at 0.5ppm.

The demand for REE is forecast to maintain a strong growth from the current level of around 124 000 tonnes per annum (tpa) REO, which has an estimated value of US\$1.5 billion, to about 190 000 to 200 000tpa in 2015 (Kingsnorth 2010)¹.

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 Eu and Tb which are used in the production of phosphors for televisions and energy efficient light globes.

⁵ Arafura Resources Ltd, 2010. Presentation to the USGS. Reston VA, USA 16 March 2010

Table 4: Applications for rare earth elements in the emerging technology areas

Application	Rare Earth Element
Light Weight Magnets	
Cars Light weight magnets in motors for windows, windscreen wipers, starter motors, alternators, etc Electronics Magnets in disc drives for computers, data storage, portable music players (eg iPods), video recorders, consoles, video cameras Speakers Wind turbines	Nd, Pr, Sm, Dy, Tb
Catalyst	
Automotive catalyst Clean diesel Oil refining	La, Ce, Nd, Pr
Hybrid vehicles	
Electric motors and generators	Nd, Pr, Dy, Tb
Hybrid batteries	La, Nd, Ce
Compact fluorescent lights	Eu, Tb, Y
Polishing powders	
TV and computer screens LCD, Plasma, CRT Optical lenses Precision optical and electronic components	Ce, La, Pr
Glass additives	
CRT screens to stabilise glass from cathode ray Small optical lenses Phosphors TV and computer screens	Ce, Er, Gd, Tb, La, Nd, Yb, Pm
Ceramics	Dy, Er, Pr, Gd, Ho, Ce, La

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. Lynas Corporation Ltd reported in its June 2010 quarterly report that export restrictions by the Chinese Ministry of Commerce resulted in a 40% decrease in available rare earth export quota in 2010 compared with 2009. This decrease coincided with the launch of a nationwide crackdown on illegal mining of rare earths in 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), 0.37Mt Paramarginal and 34.48Mt in the Submarginal

Resource categories. There is a further 24.56Mt in the Inferred Resources category. About 53Mt of the Submarginal and Inferred Resources are in the Olympic Dam iron oxide-copper-gold deposit in South Australia (SA), made up predominantly 0.2% La and 0.3% Ce, and are not currently economic. Small quantities of Sc (4620 tonnes subeconomic and 1690 tonnes inferred Sc), commonly included with rare earths, also were reported in 2010. In addition, about 4160 tonnes of Paramarginal Resources and 51 980 tonnes of Inferred Resources were reported as 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 6.1Mt. Assuming the REO content of monazite to be about 60%, the heavy mineral deposits could hold an REO resource of around 3.66Mt. Currently, extraction of rare earth from monazite is not viable because of the cost involved in the disposal of thorium (Th) and uranium (U) present in the monazite.

Table 5: Distribution of types of rare earth elements in monazite from different parts of the world (modified after Mukherjee 2007⁶).

REO	GUANGDONG CHINA weight %	TAIWAN weight %	AUSTRALIA weight %	FLORIDA,USA weight %	INDIA weight %
La ₂ O ₃	23	21	23.2	17.4	22
CeO ₂	42.7	47.9	46.3	43.7	46
Pr ₆ O ₁₁	4.1	5.4	4.9	4.9	5.5
Nd ₂ O ₃	17	18.7	18.3	17.1	20
Sm ₂ O ₃	3	3.3	2.5	4.9	2.5
Eu ₂ O ₃	<0.1	0.54	0.04	0.16	0.016
Gd ₂ O ₃	2	1.6	1.7	6.5	1.2
Tb ₄ O ₇	0.7	0.19	0.22	0.26	0.06
Dy ₂ O ₃	0.8	0.35	0.56	0.59	0.18
Ho ₂ O ₃	0.12	0.03	0.08	0.11	0.02
Er ₂ O ₃	<0.3	0.03	0.06	0.04	0.01
Tm ₂ O ₃	TR	-	-	0.03	Tr
Yb ₂ O ₃	0.24	0.07	0.04	0.21	Tr
Lu ₂ O ₃	<0.14	-	-	0.03	Tr
REO	55	48–62	58.5	-	58
Other elements					
Y ₂ O ₃	2.4	0.19	1.57	3.18	0.45
ThO ₂	4	0.41	6.4	-	9.5

Production

Historically, Australia has exported large quantities of monazite from heavy mineral sands mined in Western Australia (WA), New South Wales (NSW) and Queensland (Qld), for the extraction of both rare earths and Th. Between 1952 and 1995, Australia exported 265 kilotonne (kt) of monazite with a real export value (2008 dollars) of \$284 million (Australian Bureau of Statistics 2009)⁷.

⁶ Mukherjee, T.K. 2007. Thorium resources in India, its mining, separation and chemical processing. IAEA Technical meeting on 'Thorium based fuels and fuel cycle options for pressurized heavy water cooled reactors, light water reactors and high temperature gas-cooled reactors. 22 to 25 October, 2007. Istanbul, Turkey.

⁷ ABS, 2009b, International trade, Cat. No.5465.0, Canberra.

Small-scale production of rare earths has taken place in Australia but records on these activities are incomplete. The following information on historical attempts to establish a rare earth production industry in Australia is drawn from Cooper 1990⁸. In the 1950s, Zircon Rutile Ltd at Byron Bay, NSW, processed a small quantity of monazite to produce Ce oxide for use in glass polishing. In 1969, Rare Earth Corporation of Australia Ltd, operating at Port Pirie SA, began producing Ce, La, Y and Th compounds from locally produced monazite. However, the plant ceased operations in mid 1972 because of a lack of working capital and the difficulty of breaking into world markets for processed rare earths.

In January 1987, it was announced that the French chemical company Rhone-Poulenc would build a two-stage monazite processing plant at Pinjarra in WA to produce rare earths from monazite, but the project was suspended. Deckhand Pty Ltd, a wholly owned subsidiary of Currumbin Minerals, was blocked in 1988 on environmental grounds from establishing a rare earths processing plant at Lismore, NSW. SX Holdings Ltd of SA was planning to establish a plant at Port Pirie to process monazite with a 2000tpa cracking and separation plant but the project did not proceed.

Barrie (1965)⁹ reported that a pegmatite deposit six kilometres (km) east of the Cooglegong crossing, WA was worked in 1913 and 1930 and yielded about 2 tonnes of gadolinite (yttrium iron beryllium silicate $(\text{Ce,La,Nd,Y})_2\text{FeBe}_2\text{Si}_2\text{O}_{10}$). An analysis of Cooglegong gadolinite yielded 45.78% of yttrium trioxide (Y_2O_3) and 4.81% of other REO. Note that gadolinite does not contain more than trace amounts of gadolinium.

In 2007, mining operations commenced at the Mount Weld deposit in WA 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 the period 2007 to 2009.

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 36Mt (37.8%) of the world's economic reserves of REO, followed by the Commonwealth of Independent States with 19Mt (19.9%) REO and the USA with 13Mt (13.7%). Australia's EDR accounts for 1.73% of world's economic reserves with 1.65Mt 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 48Mt REO (EDR + Inferred + Subeconomic Resources) 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 1.8Mt REO at an average grade of about 9% REO. Deposits associated with carbonatite laterites include Araxa in Brazil with 8.1Mt REO at 1.8% and Mount Weld in WA with 1.74Mt 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 NSW, along with a peralkaline syenite deposit at Lovozero in Russia.

Industry Developments

Lynas Corporation Ltd: The Mount Weld deposit in WA is within the lateritic profile over an alkaline carbonatite complex. In September 2010 Lynas announced new resource figures for the Central Lanthanide deposit of Measured, Indicated and Inferred Resources of 9.88Mt with total lanthanide oxides (TLnO) at 10.6% and 990ppm Y_2O_3 (heavy REO) and the newly named Duncan heavy REO deposit with Measured, Indicated and Inferred resources totalling 7.62Mt at 4.5% TLnO and 2570ppm Y_2O_3 . In another part of the carbonatite complex, the Crown Polymetallic deposit, there are Indicated (1.5Mt) and Inferred (36.2Mt) Resources totalling 37.7Mt, which include total lanthanides at 1.16% and 0.09% Y_2O_3 . The company completed the first stage of mining activities in 2008 and commenced construction of a concentration plant at Mount Weld and an advanced materials

⁸ Cooper W., 1990 Queensland mineral commodity report. Queensland Government Mining Journal, September 1990. Department of Resource Industries. 383–389

⁹ BARRIE, J., 1965—Rare Earths. In McLEOD, I. R. (Editor), AUSTRALIAN MINERAL INDUSTRY: THE MINERAL DEPOSITS. Bureau of Mineral Resources, Australia, Bulletin 72, 515–521.



Construction of the concentration plant at Mount Weld rare earth project, Western Australia (Lynas Corporation Ltd)

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 September 2009, Lynas announced a fully underwritten share issue in Lynas to raise \$450 million, which will be used to complete phase 1 of the Lynas rare earths project. Lynas reported in its 2009 annual report that it had signed long term contracts with four customers to supply rare earths and signed letters of intent with another two customers. The target date for the first ore feed to the concentration plant is December 2010.

Arafura Resources Ltd: Nolans Bore rare earth-phosphate-uranium-thorium deposit is located 135km northwest of Alice Springs in the NT. It has Measured, Indicated and Inferred Resources totalling 30.3Mt to a depth of 130 metres which grades at 2.8% REO, 12.9% P₂O₅, 0.44 pounds per tonne U₃O₈, and 0.27% Th. According to Arafura, the distribution of the light REE currently being considered for extraction, (La, Ce, Pr, and Nd) amount to 95% whereas the heavy REE (Sm, Eu, Gd, Tb, Dy) amount to 4.23%. 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) for ECE to acquire up to 25% of the issued capital of Arafura through two share placements. The proposal was approved by the Australian Foreign Investment Review Board in May 2009 and accepted by the shareholders in September 2009. The company is conducting a definitive feasibility study on the Nolans Bore project and, in July 2010, reported that it is on track to commence production in 2013¹⁰.

Alkane Resources Ltd: The company's Dubbo Zirconia Project located 30km south of Dubbo in NSW has a reported Measured Resource of 35.7Mt and 37.5Mt of Inferred Resources grading 1.96% ZrO₂, 0.04% HfO₂, 0.46% Nb₂O₅, 0.03% Ta₂O₅, 0.14% Y₂O₃, 0.745% total REO, 0.014% U₃O₈, 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) facility at Lucas Heights in NSW. Alkane reported that the DPP completed two trial runs in 2008 and one more in the first quarter of 2009, producing high quality zirconium (Zr) and niobium (Nb) products. In November 2009, Alkane reported that the plant had produced the first light REE and Y-heavy REE products and stressed the importance of the rare earths as a revenue earner, particularly the heavy REE. The current plans are to make a decision on development during the second half of 2010 with production to commence in 2011–12 if development goes ahead.

¹⁰ <http://www.arafuraresources.com.au/documents/July2010AdvertorialFINAL.PDF> accessed September 2010.

Navigator Resources Ltd: The company's Cummins Range carbonatite deposit occurs in the southeast part of the Kimberley region in WA. In September 2009, it reported Inferred Resources of 4.17Mt at 1.72% total REO, 11.0% P₂O₅, 187ppm U₃O₈ and 41ppm Th at a cut-off grade of 1% total REO. The total REO was subdivided into 95.6% light REO (La, Ce, Pr, Nd), 4.1% middle REO (Sm, Eu, Gd, Tb, Dy) and 0.3% heavy REO (Ho, Er, Tm, Yb, Lu). A mineralogical investigation of the Cummins Range deposit by the CSIRO Minerals Down Under Flagship was completed during the March 2010 quarter with the principal rare earth bearing minerals being primary apatite and monazite and only subordinate amounts of secondary rare earth bearing minerals are present.

Capital Mining Limited: Similarly the peralkaline granitic intrusions of the Narraburra Complex 177km northwest of Canberra contain anomalous amounts of zirconium, REO and low concentrations of Th (55Mt at 1000 grams per tonne (g/t) ZrO₂, 60g/t Y₂O₃, 300g/t REO, 40g/t HfO₂, 80g/t NbO₂, and 50g/t ThO₂, Capital Mining Limited Prospectus 2006). The thorium oxide (ThO₂) content amounts to 2750 tonnes (2420 tonnes Th). In the March quarterly report in 2010, the owners of the project, Capital Mining Limited, reported that it was conducting metallurgical test to recover hafnium (Hf), Th, tantalum (Ta), Nb, Nd and Ce.

Artemis Resources Limited: Historic exploration records reported that the Yangibana ferrocarnatite-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 REE fluorite and U-Th mineralisation. The Yangibana prospect has a recorded resource of 3.5Mt at 1.7% REO. The rare earths are in coarse grained monazite containing up to 20% Nd₂O₅ and 1600ppm Eu₂O₃. Artemis Resources Limited reported in its December 2009 quarterly report that it had acquired the Yangibana rare earth prospect.

Marathon Resources Limited: In August 2005 Marathon reported that an Inferred Resource of 51 800 tonnes La-Ce is associated with the uranium deposit at Mount Gee, about 520km north northeast of Adelaide in SA.

BHP Billiton Limited: About 53Mt of the Submarginal and Inferred Resources are in the Olympic Dam iron oxide-copper-gold deposit in SA (predominantly 0.2% La and 0.3% Ce) and are not currently economic.

The historic uranium mine of Mary Kathleen in northwest Qld is essentially a uranium-rare earths skarn deposit which has a remnant resource in tailings of about 5.5Mt at 6.4% REO +Y. Commonly occurring REE minerals in the original deposit were stillwellite and allanite while other REE-bearing minerals included apatite, titanite and garnet.

During the past couple of years Sc bearing lateritic nickel-cobalt (Ni-Co) deposits have attracted increasing attention in response to anticipated rise in demand for Sc. Zirconia stabilised with Sc rather than Y as an electrolyte for Solid Oxide Fuel Cells (SOFCs) reduces the operating temperature of the fuel cell significantly, thereby providing a much longer life. SOFCs are expected to play a major role in the developing battery powered electric transportation industry (cars, trucks, trains, etc) as well as in stationary applications, such as electricity generation in the home or as a substitute for coal fired power plants¹¹.

Metallica Minerals Limited: During 2010 Metallica announced scandium resources located within their Kokomo and Lucknow lateritic Ni-Co deposits in Qld. The Kokomo deposit is 50km north northeast of Greenvale and the Lucknow deposit is 2km south of Greenvale which is about 190km west northwest of Townsville. In January the company reported a Measured, Indicated and Inferred Resource for the Kokomo deposit totalling 9Mt grading 109g/t Sc, 0.24% Ni and 0.03% Co associated with a lateritic Ni-Co deposit of 16.3Mt at 0.67% Ni, 0.12% Co and 36g/t Sc. In August 2010, Indicated and Inferred Resources were also reported for the Lucknow deposit totalling 6.1Mt grading at 169g/t Sc, 0.2% Ni and 0.04% Co delineated at a cut-off-grade of 70g/t Sc. The total Sc resource for the two deposits amounts to 15.1Mt at 133g/t Sc, 0.22% Ni, 0.04% Co. The contained scandium metal in the two deposits amounts to approximately 2000 tonnes Sc.

The Lucknow deposit includes a high grade zone at a cut-off-grade of 120g/t Sc, the Red Fort, measuring 4.09Mt of Indicated and Inferred Resources at 205g/t Sc, 0.22% Ni and 0.05% Co.

Metallica also announced in September 2010 that it was following up the positive results of an initial scoping study on its Ni-Co and Ni-Co-Sc deposits with additional metallurgical studies and resource drilling before committing to a full feasibility study.

¹¹ EMC Metals Corporation of Canada in a press release on 8 February 2010 on the Toronto Stock Exchange.

Jervois Mining Ltd: In June 2005 the company reported that its Nyngan lateritic nickel-cobalt-scandium-platinum deposit in NSW had a resource of 16Mt at 0.87% Ni and 0.06% Co. An Sc-rich portion of this deposit was updated in June 2009 as Measured Resources of 2.718Mt at 274ppm Sc and Indicated Resources of 9.294Mt at 258ppm Sc. Jervois, in a joint venture agreement with EMC Metals Corporation of Canada, is currently engaged in scoping studies to provide data for a pre-feasibility study of the Nyngan Sc joint venture project in mid 2011.

Shale Oil

Leesa Carson (leesa.carson@ga.gov.au)

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 of oil.

Resources

The majority of oil shale resources of commercial interest are located in a series of narrow and deep extensional-basins near Gladstone and Mackay in central Queensland (Qld). These are thick Cenozoic 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 northwest Qld. Oil shale deposits of varying quality are located in the Sydney Basin, New South Wales (NSW), 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 historic 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) (about 1340 million barrels) and 2074GL (about 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 1272GL (about 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 1983¹². 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 000GL was based on productive oil shale covering an area of 484 000 square kilometres and ranging from 6.5 to 7 metres (m) thick with a specific gravity of 1.9 and yielding an average 37L of oil per tonne.

Exploration

In Qld, the majority of exploration activities are in care and maintenance since the Queensland Government announced a 20-year moratorium on oil shale development in the Whitsunday region and a two year review into the oil shale industry. Previously, exploration was predominantly focused near Gladstone and Mackay in central Qld and in northwest Qld. In Tas, southeast of Devonport, Boss Energy Ltd is continuing to undertake exploration work at the Latrobe oil shale deposit and Eagle Nickel Ltd is assessing exploration tenements adjacent to the Latrobe project. 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

¹² 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.

using a horizontal rotating kiln process (Alberta Taciuk Process). No oil has been produced since 2004. The facility has been dismantled and the site remediated.

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 one 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 2010 Survey of Energy Resources by the World Energy Council (WEC) reported that total world **in-place** resources of shale oil are estimated at 4.8 trillion barrels. The largest known deposit is in the western USA (3 trillion barrels in-place resource), with other important deposits in China, Russian Federation, the Democratic Republic of the Congo, Brazil, Italy, Morocco, Jordan, Australia and Estonia. Only Estonia, China and Brazil produce shale oil. The WEC survey reported that total oil production at the end of 2008 was about 1165 million litres (ML), with Estonia producing 445 ML, China 470 ML and Brazil 250 ML.

Industry Developments

In November 2008, Queensland 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 variation of existing entitlements have 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. The report is yet to be released.

In Qld, companies have either scaled back investment or revised projects. These companies include:

- Queensland Energy Resources Ltd (Stuart Project, Qld) which, in mid 2010, commenced construction of a small-scale technology demonstration plant using Paraho vertical shaft kiln processing system.
- Blue Ensign Technologies Ltd (Julia Creek Project (south), northwest Qld) which as at June 2009 was planning to build a demonstration plant to test the thermal solution technology (Rendall Process), a thermal conversion and hydrogenation, followed by supercritical solvent extraction.
- Greenvale Mining NL (Alpha project, Qld) which continues to review the viability of Vertical Retort Torbanite (VRT) processing technology being developed by a South African based company. Samples from the Alpha project have been sent to Johannesburg for testing.
- Xtract Energy Plc (Julia Creek Project (north), NW Qld) which continues to maintain its tenements, but has scaled back investment in the development of the Xtract technology, a hydrogen and supercritical solvent extraction process. In Tas, Boss Energy Ltd has engaged the Chinese company, Fushun Mining Group, to carry out tests on tasmanite oil shale samples from the Latrobe project to determine physical and chemical properties and key operating parameters.

Tantalum

Leesa Carson (leesa.carson@ga.gov.au)

Roy Towner (roy.towner@ga.gov.au)

The main use of tantalum (Ta) is in the manufacture of capacitors required for the electronics and telecommunications industries. Because they are small and have high reliability, these capacitors are used in miniaturised electronic circuits, mainly in mobile phones. Tantalum metal is used also 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 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 at Wodgina 100km south of Port Hedland, WA, has historically been the world's largest producer of tantalum (as tantalite concentrates), providing approximately half of the world's mine output.

Resources

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

Australia's Economic Demonstrated Resources (EDR) are estimated to be 51 kilotonnes (kt) of tantalum in 2009, which is unchanged from 2008. All of the EDR are in WA with more than 98% associated with Talison Minerals' Greenbushes and Wodgina deposits.

Subeconomic Demonstrated Resources account for about 24% of total Demonstrated Resources. The Paramarginal and Submarginal Resources amount to 15kt and 0.2kt, respectively. New South Wales (NSW) is the largest holder of Paramarginal Resources with 57% followed by WA with 43%. All the Submarginal Resources occur in WA.

Inferred Resources decreased by 57% to 31kt in 2009, as a result of the removal from the national inventory of historical estimates which pre-date the Joint Ore Reserve Committee (JORC) Code and do not comply with the requirements of the code. WA and NSW account for 70% and 30% respectively of Inferred Resources.

Accessible EDR

All of Australia's EDR of tantalum is accessible.

JORC Reserves

JORC Code reserves comprise total tantalum in Proved and Probable Ore Reserves as defined in the JORC Code. In 2009, JORC Code reserves of 19kt accounted for approximately 37% of Accessible Economic Demonstrated Resources (AEDR).

Exploration

Data on exploration expenditure for tantalum are not available.

Production

According to the Western Australian Department of Mines and Petroleum, 105 tonnes of tantalite concentrates contained an estimated 22 tonnes of tantalum was produced in 2009, a decrease of almost 85% on 2008 tantalite production of 680 tonnes (approximately 142 tonnes of contained tantalum).

World Resources and Production

Based on estimates published by the United States Geological Survey (USGS) and Geoscience Australia, the world resources of tantalum in 2009 totalled 116kt, although this figure is not complete for 2009. The world's largest holder of tantalum resource is Brazil with an estimated 65kt, followed by Australia with 51kt.

World production of tantalum in 2009 was estimated by Geoscience Australia (using Western Australian Department of Mines and Petroleum and USGS data) to be 622 tonnes (750 tonnes in 2008). Production in 2009 was dominated by Brazil, with 180 tonnes, which amounted to about 29% of world output, although this figure is not complete for 2009. According to the USGS, other main producers were Congo and Rwanda with 100 tonnes each and Canada with 40 tonnes.

Industry Developments

Mining at Talison Minerals' **Wodgina** operation has been suspended since December 2008. The operation, which has a production capacity of 1.3 million pound per annum of tantalum pentoxide (Ta₂O₅),

mines tantalum-bearing pegmatite ores from the Mount Cassiterite and South Tinstone open pits. The ores are crushed, milled and fed into the advanced gravity separation plant. The Wodgina plant produces primary tantalum concentrate, grading between 8% and 10% Ta₂O₅ which is transported by road train to the Greenbushes plant for secondary processing to produce saleable tantalum products.

Talison Minerals' **Greenbushes** operations in WA, consist of an open pit operation, an underground mine, primary and secondary tantalum processing plants, tin smelter and a lithium plant. The company's primary tantalum plant remains on care and maintenance. Its secondary processing plant treats primary tantalum concentrates from the Wodgina mine. The tin smelter is closed. The Greenbushes lithium operation produces various grades of spodumene products (see Lithium Chapter).

Galaxy Resources Limited commenced mining from the Dowling Pit, part of the **Mount Cattlin** lithium project, north north-east of Ravensthorpe, WA. The Mount Cattlin deposit has a reported JORC Code compliant resource of 14.4 million tonnes, with average grade of 1.08% Li₂O and 153 parts per million Ta₂O₅ for an estimated 155 000 tonnes of Li₂O and 219 000 tonnes of Ta₂O₅. Commissioning of its onsite processing plant started in September 2010. At full production, the project is expected to produce 137 000 tonnes per annum of spodumene concentrate grading 6% lithium oxide (Li₂O) and 56 000 pounds per annum of contained Ta₂O₅ in concentrate.

Alkane Resources Ltd's demonstration pilot plant at ANSTO Minerals at Lucas Heights in Sydney, NSW, has been processing an initial 100 tonnes of ore from the **Toongi** deposit (referred to as the Dubbo Zirconia project). The plant has recovered several tonnes of zirconia concentrate, niobium-tantalum concentrate, and yttrium-rare-earth concentrate. A development decision by the company for the project is expected in late 2010.

Thorium

Yanis Miezitis (yanis.miezitis@ga.gov.au)

Thorium oxide (ThO₂) 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 ²³³U 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 three stage nuclear fuel cycle to utilise its abundant thorium resources. 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. It will have a blanket with thorium and uranium to breed fissile ²³³U and plutonium respectively. This project will take India's thorium program to stage 2. In stage 3 Advanced Heavy Water Reactors (AHWRs) burn ²³³U and plutonium with thorium to derive about 75% of the power from thorium. However, full commercialisation of the AHWR is not expected before 2030.

In September 2009 India announced an export version of the AHWR—the AHWR-LEU. This design will use low-enriched uranium plus thorium as a fuel, dispensing with the plutonium input. About 39% of the power will come from thorium (via in situ conversion to ²³³U). The uranium enrichment level will be 19.75%, giving 4.21% average fissile content of the uranium-thorium fuel. Plutonium production will be less than in light water reactors, and the fissile proportion will be less, providing inherent proliferation resistance benefits. This version can meet the requirement also of medium sized reactors in countries with small grids while meeting the requirements of next generation systems (Kakodkar 2009).¹³

Atomic Energy of Canada Ltd (AECL) has reported that some countries are assessing the use of thorium fuels in existing CANDU 6 (700MWe class) reactors. In July 2009, AECL signed agreements with three Chinese entities to develop and demonstrate the use of thorium fuel in the CANDU 6 reactors at Qinshan in China.

A company in the USA, Lightbridge Corporation is developing thorium-uranium fuel for the existing

¹³ Kakodkar A, 2009, Statement by Dr Anil Kakodkar, Chairman of the Atomic Energy Commission and leader of the Indian delegation, IAEA 53rd General Conference, Vienna, 16 September 2009.

Russian Vodo-Vodyanoi Energetichesky reactors (VVER-1000) and for use in existing pressurised light water reactors (PWR).

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 four more planned and another four proposed. The thorium fuel design for the PWRs is aimed at 'western-style' reactors of which there were about 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 (now Lightbridge Corporation) signed an initial collaborative agreement on 23 July to investigate the potential use of thorium in Areva's Evolutionary Power Reactor (EPR). This was followed by a five year consulting agreement signed on 3 August 2009 (Lightbridge Corporation presentation to Deutsche Bank Conference 11 May 2010 <http://ir.ltbridge.com/phoenix.zhtml?c=121550&p=irol-irhome>).

Resources

Australia's total Indicated and Inferred in-situ resources of thorium amounts to about 539 000 tonnes. Because 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, the recoverable resources of Australia's thorium could amount to about 485 000 tonnes.

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

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

THORIUM RESOURCES IN HEAVY MINERAL SAND DEPOSITS

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 returned back to the pit in dispersed form, as stipulated in mining conditions, 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 (WA). Heavy mineral sands are being mined in the Murray basin deposits at Ginkgo in New South Wales and at Douglas in Victoria.

Using available data, Geoscience Australia estimates Australia's monazite resources in the heavy mineral deposits to be around 6.1 million tonnes (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
- 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 372 000 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. Thorium is usually associated in these

deposits with other commodities such as rare earths, zirconium, niobium, tantalum and other elements. The more significant deposits are described in the following paragraphs.

THORIUM RESOURCES IN VEIN-TYPE DEPOSITS

Arafura Resources Ltd: Nolans Bore rare earth-phosphate-uranium-thorium deposit is located 135 kilometres (km) northwest of Alice Springs in the Northern Territory (NT). The mineralisation is hosted in fluorapatite veins and dykes. This deposit contains about 81 810 tonnes of Th in 30.3Mt of Measured, Indicated and Inferred Resources grading 2.8% rare earth oxides (REO), 12.9% P₂O₅, 0.02% U₃O₈ and 0.27% Th.

THORIUM RESOURCES IN ALKALINE ROCK COMPLEXES

Alkane Resources Ltd: The Toongi zirconium-niobium-rare earth deposit occurs within an alkaline trachyte plug about 30km south of Dubbo in New South Wales (NSW). The deposit has a Measured Resource of 35.7Mt and 37.5Mt of Inferred Resources grading 1.96% ZrO₂, 0.04% HfO₂, 0.46% Nb₂O₅, 0.03% Ta₂O₅, 0.14% Y₂O₃, 0.745% total REO, 0.014% U₃O₈, and 0.0478% Th, giving a total of about 35 000 tonnes contained Th. A Demonstration Pilot Plant (DPP) was constructed and commissioned in May 2008 at the **Australian Nuclear Science and Technology Organisation** (ANSTO, <http://www.ansto.gov.au>), Lucas Heights. The DPP is designed to test the flowsheet for the ore from Toongi 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.

Mount Gibson Iron Ltd: Other alkaline complexes with known rare earth and thorium mineralisation include Brockman in WA. It is a large low-grade zirconium-niobium-rare earth element (Zr-Nb-REE) deposit hosted in altered trachytic tuff of Paleoproterozoic age containing mineralised material of 50Mt at 4400 parts per million (ppm) 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 16 metres (m) to 28m averaging from 259-371ppm Th (Western Australia Geological Survey WAMEX database report A 40991).

THORIUM RESOURCES ASSOCIATED WITH CARBONATITE INTRUSIONS

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

Lynas Corporation Ltd: The Mount Weld deposit in WA occurs within a lateritic profile developed over an alkaline carbonatite complex with a reported measured, Indicated and Inferred REO resource of 12.24Mt at 9.7% REO. The ThO₂ 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 orebody of the carbonatite complex of 2.78Mt of Measured, Indicated and Inferred Resources at 4% REO with an estimated ThO₂ content of 441ppm (388ppm Th). In another part of the carbonatite complex there are 37.7Mt of mostly Inferred Resources which include total lanthanides at 1.16% and 0.09% Y₂O₃ and a ThO₂ content of 479ppm (421ppm Th).

Navigator Resources Ltd: In March 2008, Navigator Resources reported Inferred Resources for Cummins Range in WA carbonatite deposit of 3.55Mt at 2% REO, 11.2% P₂O₅, 216ppm U₃O₈ 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 200–400ppm Th were intersected in two drill holes in fresh carbonatite and carbonated magnetite amphibolite to depths of 400m.

Artemis Resources Ltd: The Yangibana ferrocarnatite-magnetite-rare earth-bearing dykes in WA (termed 'ironstones') crop out over an area of 500 square kilometres and form part of the Gifford Creek Complex. The dykes are part of a carbonatitic episode which intrudes the Proterozoic Bangemall Group. The ferrocarnatite-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 uranium-thorium mineralisation. The Yangibana prospect has a recorded resource of 3.5Mt at 1.7% REO. The rare earths are in coarse grained monazite containing up to 20% Nd₂O₅ and 1600ppm Eu₂O₃. 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).

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 in the NT and in the Toongi intrusives complex in NSW. Heavy mineral concentrations within the King Leopold Sandstone and the Warton Sandstone, which constitute the Durack Range uranium project in WA, 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 the NT with 599–1400ppm 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 WA. Most of the monazite was exported to France for extraction of REE, 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.

Table 6: Estimated thorium resources by country

Country	Total Identified Thorium Resources (Reasonably Assured + Inferred Resources)** ('000 tonne Th) <USD 80/kg Th
Australia	485
United States of America	400
Turkey	Not available
India	319
Brazil	302
Venezuela	300
Norway	132
Egypt	100
Russian Federation	75
Greenland	54
Canada	44
South Africa	18
Others	33
TOTAL	2262

Sources: Data for Australia compiled by Geoscience Australia; estimates for all other countries are from: OECD/NEA & IAEA, 2009: Resources, Production and Demand. OECD Nuclear Energy Agency & International Atomic Energy Agency. **See Uranium chapter for definitions of resource categories

World Ranking

The Organisation for Economic Cooperation and Development/Nuclear Energy Agency OECD/NEA & International Atomic Energy Agency (IAEA) (2009)* have 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 6 has been derived by Geoscience Australia from information presented in the OECD/NEA analysis. The total identified resources refer to Reasonably Assured Resources (RAR) plus Inferred Resources recoverable at less than US\$80/kilogram Th.

OECD/NEA & IAEA (2009) have grouped thorium resources according to four main types of deposits as shown in Table 7. Thorium resources worldwide appear to be moderately concentrated in the carbonatite type deposits accounting for about 30% of the world total. 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 are located in placers where the heavy mineral sand deposits account for about 70% of the known thorium resources in Australia.

Table 7. World and Australia's thorium resources according to deposit type (modified after OECD/NEA and IAEA, 2009) 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 tonnes Th)	Percentage	Resources (1000 tonnes Th)	Percentage
Carbonatite	1900	31.3	24	4.9
Placer deposits	1500	24.7	335	69.1
Vein-type deposits	1300	21.4	73	15.1
Alkaline rocks	1120	18.4	53	10.9
Other	258	4.2	No data	-
Total	6078	100.0	485	100.0

Tin

Roy Towner (roy.towner@ga.gov.au)

Aden McKay (aden.mckay@ga.gov.au)

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 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 tinfoil, which accounts for about 16% of world tin consumption. Tinfoil 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) of tin increased by 21% to 176 kilotonnes (kt) at December 2009, up from 145kt in 2008. This resulted from a large increase in tin resources at Scotia in Tasmania (Tas) and Gillian in Queensland (Qld).

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

Accessible EDR

All of Australia's EDR for tin are unencumbered.

JORC Reserves

Joint Ore Reserve Committee (JORC) Code reserves comprise total tin in Proved and Probable Ore Reserves as defined in the JORC Code. In 2009, JORC Code reserves of 47kt Sn accounted for approximately 27% of Accessible Economic Demonstrated Resources (AEDR).

Exploration

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

Venture Minerals announced an Inferred Resource for the **Mount Lindsay** magnetite-tin prospect of 23 million tonnes (Mt) averaging 0.2% Sn for 49 000 tonnes of contained tin as well as an Inferred Resource of tungsten of 5.7Mt averaging 0.3% tungsten oxide (WO₃) for 14 000 tonnes of tungsten oxide. These resources are contained in, or immediately adjacent to, an Inferred Resource of 30Mt averaging 33% iron (Fe). The Mount Lindsay prospect is located 15 kilometres (km) northwest of Renison Bell tin mine and 20km west of Rosebery in western Tas. The prospect is in magnetite (Fe₃O₄)-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 on King Island in Bass Strait. In the 2008/2009 year, Venture Minerals completed a 15 000 metres (m) diamond core program focussing on the Main Zone and the No. 2 Zone. Significant drill intersections recorded from this program were 46m averaging 0.1% Sn and 0.61% WO₃, including 12m averaging 0.11% Sn and 1.69% WO₃ as well as 40m averaging 0.09% Sn and 0.4% WO₃ and 18m averaging 2.2% Sn, 0.23% WO₃ which included 2m averaging 14% Sn and 0.26% WO₃.

Malachite Resources continued exploration at a number of historic tin deposits in the Inverell district in northern NSW—mainly **the Sheep Station Hill** greisen deposit, **Karaula** alluvial-tin-tungsten deposit at **Newstead** and the Standon vein prospect. The Karaula alluvial deposit occurs as flat-lying paleoalluvial material partly draped around Bruce's Hill at Newstead. Tin grades vary from less than 0.1kg per cubic metre Sn to 5kg per cubic metre of contained tin occurring as cassiterite.

YTC Resources Ltd continued exploration at the **Giants Den** alluvial deposits including historic alluvial tin mines at Watson's Creek and Fish Creek near Bendemeer, in northern NSW. The Giants Den mineralisation occurs as cassiterite and chalcopyrite in sheeted quartz-greisen veins, over an area of 400m by 600m. However, the company reported that the overall results from its 72 holes drilling program were disappointing. Within YTC Resources' **Doradilla** project 55km southeast of Bourke, NSW, the Doradilla-Midway-3KEL tin deposits occur within a linear skarn unit which can be traced for more than 17km along strike. The top 40–60m of the skarn is 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. The company has announced a combined Inferred Resource for the tin laterite (oxide) mineralisation of 7.81Mt averaging 0.28% Sn (at a cut-off grade of 0.1% Sn) for 22.3kt of contained tin. At its **Tallebung** tin-tungsten deposit, 70km northwest of Condobolin in central NSW, YTC completed an initial program of six diamond drill holes with the following significant drill intersections reported: 24m averaging 0.23% Sn and 0.12% W; 17.7m averaging 0.22% Sn and 20 parts per million silver (Ag), and 16m averaging 0.15% Sn.

Carpentaria Exploration Ltd reported that work at the **Euriowie** project, 60km north of Broken Hill, NSW, located tin pegmatites which have not been subjected to modern exploration techniques and have not been tested by drilling. Ten traverses consisting of several 1m continuous rock chip samples were taken across the outcropping pegmatite. Results included: 8m averaging 0.44% Sn including 1m averaging 1.21% Sn; and 6m averaging 0.36% Sn which included 1m averaging 1.60% Sn.

In the Mount Garnet tin field 200km southwest of Cairns, Qld, Consolidated Tin Mine Ltd (CTM) completed 6300m of drilling at the **Gillian** (5km southwest of Mount Garnet), **Pinnacles** (6km northeast of Mount Garnet) and **Deadman's Gully** (25km northeast of Mount Garnet) tin deposits. These deposits are in iron-rich skarns adjacent to granitic intrusions. Significant intersections include 13m at 2.02% Sn and 36m at 1.2% Sn. In April 2010, the company announced a revised total JORC Code resource of 5.2Mt at 0.64% Sn, 5.42Mt at 26.45% Fe and 0.96Mt at 15.25% fluorine (F) for its Mount Garnet project. Within this total resource, the JORC Code

Measured Resource at the Gillian deposit increased to 1.2Mt at 0.82% Sn from the previous Measured Resource of 724 700 tonnes at 0.8% Sn. The company continued investigations into various metallurgical techniques to separate the fine cassiterite from the ironstone skarn material.

Xtremes Resources Limited commenced exploration at a number of historic tin mines including **Dalcouth, Summer Hill, Extended, Tom Hood** and **Smiths Creek** in the immediate proximity of the Mount Veteran tin plant and smelter, all located in the Mount Garnet District, north Qld. A 100kg sample of weathered oxidised ore from the Dalcouth open cut returned an average grade of 0.86% Sn. The company anticipates that the former mill will be fully functional by early 2011.

Outback Metals continued resource estimation of its **Mount Wells** tin-copper deposit 200km southeast of Darwin in the Northern Territory (NT).

Production

Australia's mine production in 2009 was 5630 tonnes of tin in concentrates, three times more than the 2008 production of 1783 tonnes. The increase in Australia's mine production resulted from Metal X's resuming mining operations in Tas. There has been no production of refined tin in Australia since 2007 when 118 tonnes of refined tin ingots was produced from smelting of concentrates at Greenbushes (WA). Total exports for 2009 were 6086 tonnes valued at \$97 million which compared with 2784 tonnes valued at \$45 million in 2008.

World Ranking

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

Industry Developments

The tin price (London Metal Exchange) started the financial year in July 2008 at a high of US\$23 500 a tonne (A\$24 600) and with the onset of the financial crisis reached a low point of US\$10 000 a tonne (A\$14 400) in late December 2008. The price has recovered since and ranged from US\$17 500 to US\$18 000 a tonne in mid 2009.

Metals X Limited, Australia's main hard-rock tin mining company, has operations in western Tas at the historic **Mount Bischoff** open cut 80km north of Renison and at the **Renison Bell** underground mine near Zeehan. Ores from both mines were blended for feed to the Renison concentrator which, after minor modifications and additions to the plant during the year, reached a throughput capacity of about 80 tonnes per hour.

In July 2009, Metals X Limited signed a Heads of Agreement with the world's largest tin producer China's Yunnan Tin Group Company Limited (YTG) to sell to YTG up to 60% of its Tasmanian tin assets for \$60 million and to form a joint venture to operate and advance the tin mines.

Metals X Limited completed an additional 60m of vertical development at its South Renison Decline. It plans to mine ore from both North Renison and South Renison Declines at about 60 000 tonnes per month to coincide with the cessation of the first stage of the Mount Bischoff mine development. Production has commenced at North Renison Decline following de-watering of the Decline. Resources at **Renison Bell** have increased to 7.2Mt grading 1.82% Sn, representing 131 677 tonnes of contained tin.

Metals X Limited completed a feasibility study on proposals to recover tin from tailings produced by historic processing of tin ores at Renison Bell mine. Resources in the tailings dam were estimated to be 18.4Mt averaging 0.44% Sn and 0.21% copper (Cu), which represents 80 600 tonnes of contained tin and 38 800 tonnes of contained copper. The recovery project involves reclaiming tailings at a rate of 2Mt a year to produce about 5300 tonnes of tin and 2000 tonnes of copper contained in concentrates a year. The company reported that a combination of sulphide flotation and tin flotation techniques would produce a 10% Sn concentrate which could be smelted to produce a tin fume product assaying in excess 68% Sn.

Metals X's **Collingwood** mine, 30km southwest of Cooktown in north Qld, remains under care and maintenance since its closure in mid-2008. The company is reviewing its options for the sale of the assets.

In February 2009, Van Dieman Mines (VDM) went into administration as a result of start-up problems at its **Scotia** and **Endurance** alluvial tin and sapphire deposits in northeast Tas, and the refusal of a major shareholder,

Galena Special Situations Master Fund, to advance further funds. The Scotia and Endurance projects had a planned capacity of 1300 tonnes per year of tin-in-concentrates and were expected to generate by-product revenues from sales of sapphires. However, tin grades were lower than expected and very few sapphires were recovered during trial mining. In mid 2010, expressions of interest were sought for the purchase of alluvial tin resources and for associated mineral processing infrastructure located near Gladstone, Tas.

Stonehenge Metals Ltd's Heemskirk gravity separation mill at the Granville tin project 20km north of Zeehan in western Tas, has been on care and maintenance since November 2008 as a result of ore handling problems associated with wet clay-rich ores, and because of lower tin prices. The Granville project, which is now subject to a sale agreement with McDermott Mining Pty Ltd, comprises the Granville East and Central Big 'H' deposits, both of which are strata-bound carbonate replacement type deposits, and the North Heemskirk deep lead alluvial deposit.

At **Greenbushes** mine, in southwest WA, production of tin ceased in 2007 with the closure of the smelter. Tin resources for Greenbushes operations have not been publicly reported for more than a decade. Previous historical estimates of tin resources for Greenbushes have not been included in Australia's EDR since 2008.

Tungsten

Roy Towner (roy.towner@ga.gov.au)

Aden McKay (aden.mckay@ga.gov.au)

Tungsten (W) metal and its alloys are amongst the hardest of all metals. It occurs as wolframite, (Fe, Mn) WO₄, which is an iron manganese tungstate mineral, and scheelite, CaWO₄. 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.

Ferrotungsten (FeW) is a high value-added intermediate product and is used in steels and alloys where hardness and heat resistance is required.

Resources

Australia's total Economic Demonstrated Resources (EDR) at December 2009 was 195.5 kilotonnes (kt) W, an increase of 75% on the resources in 2008 (111.5kt). The tungsten EDR increased in Tasmania (Tas) by 77% and in Queensland (Qld) by 116%.

Australia's EDR are in deposits at Dolphin and Bold Head on King Island (Tas), at Watershed (Qld), Big Hill and Mount Mulgine in Western Australia (WA) and Molyhil in the Northern Territory (NT).

The bulk of Australia's EDR of tungsten occurred in Tas with 61% followed by Qld with 27%, and WA with 7%.

In 2009, Subeconomic Demonstrated Resources (comprising Paramarginal and Submarginal Resources), which account for about 1% of the total Demonstrated Resources, remained unchanged from 2008. Qld accounts for 62% of Subeconomic Demonstrated Resources followed by Tas with 38%.

Inferred Resources increased by about 160% from 79kt in 2008 to 204kt in 2009. WA accounts for 71%, followed by Tas with 11% and Qld with 10%.

Accessible EDR

All of Australia's EDR for tungsten are unencumbered.

JORC Reserves

Joint Ore Reserve Committee (JORC) Code reserves comprise total tungsten in Proved and Probable Ore Reserves as defined in the JORC Code. In 2009, JORC Code reserves of 40.3kt accounted for approximately 21% of Accessible Economic Demonstrated Resources (AEDR).

Exploration

Increase in the demand for tungsten, together with restrictions on exports of tungsten concentrates from China, has led to an increase in exploration and re-evaluation of old, previously abandoned tungsten mines and deposits, mainly in north Qld, Tas and WA. Data on exploration expenditure for tungsten are not reported by the Australian Bureau of Statistics.

Drilling by Peel Exploration Ltd intersected shallow, high-grade tungsten at the **Attunga** deposit 20 kilometres (km) north of Tamworth in New South Wales (NSW). Results include 27 metres (m) grading 0.54% WO₃, 0.06% molybdenum (Mo) from 19m, including 2m grading 3.38% WO₃ and 0.27% Mo from 22m; and 2m grading 0.59% WO₃ and 0.03% Mo from 58m. Mineralisation at the deposit occurs within skarns developed at the contact of a lime-rich sequence with the Inlet Monzonite. At least five other outcrops of tungsten mineralised skarn in close proximity to the Inlet Monzonite have been identified as having potential for the discovery of additional resources.

Venture Minerals Limited announced an Inferred Resource for the **Mount Lindsay** magnetite-tin-tungsten (Fe₃O₄-Sn-W) project of 23 million tonnes (Mt) grading 0.2% Sn for 49 000 tonnes of contained tin, 5.7Mt grading 0.3% WO₃ for 14 000 tonnes of tungsten oxide. These resources are contained in, or immediately adjacent to an Inferred Resource of 30Mt grading 33% Fe. Drill intersection reported at the project include 46m grading 0.1% Sn, 0.61% WO₃, including 12m at 0.11% Sn and 1.69% WO₃, 40m at 0.09% Sn and 0.4% WO₃ and 18m at 2.2% Sn and 0.23% WO₃, which included 2m at 14% Sn and 0.26% WO₃.

Frontier Resources Ltd announced that selective resampling and assaying of the core from the **Narrawa** gold-base metal deposit for tungsten returned encouraging results, including one metre grading 1.98% WO₃ within a broad low-grade geochemical halo that averaged 14m grading 0.20% WO₃. Narrawa is 40km southwest of Devonport, Tas.

Hazelwood Resources Ltd has released a resource estimate at a cut-off grade of 0.10% WO₃ for the **Big Hill** deposit of Measured Resources of 9.51Mt averaging 0.16% WO₃, Indicated Resources of 4.51Mt grading 0.16% WO₃, and Inferred Resources of 2.21Mt grading 0.14% WO₃ for a total resource of 16.22Mt averaging 0.16% WO₃. The deposit is part of the **Cookes Creek** tungsten project located 70km from Nullagine, WA. The company reported that drilling at the **McLeods** prospect, 1.6km west of the Big Hill deposit intersected coarse grained scheelite mineralisation adjacent to old mine workings. Intersections included 2m at 1.27% WO₃ within a zone of 9m grading 0.43% WO₃ and 13m grading 2.42% WO₃, including 2m at 13.43% WO₃.

Production

During 2009, 8 tonnes of high-grade scheelite concentrates (averaging 75% WO₃) together with 110kt of magnetite was produced at the Kara scheelite mine near Hampshire in northwest Tas, representing 3.6 tonnes of contained tungsten. The scheelite and magnetite were produced from skarn within Ordovician limestone adjacent to the contact with Devonian granite. There was no production in 2009 from the Wolfram Camp tungsten-molybdenum (W-Mo) mine, 90km west of Cairns, in north Qld.

World Ranking

In 2009, world economic resources of tungsten are estimated to be 2995kt, based on the United States Geological Survey (USGS) data which has been updated by Geoscience Australia for Australia's resources. According to the USGS, China holds approximately 60% of the resources followed by Russia with 8%, Australia with 7% and the USA with 5%.

The USGS estimates that world production of tungsten in 2009 amounted to 58kt compared with 56kt in 2008. China was the major producer with 81% of world production, followed by Russia (4%) and Canada (3%). USA production was not recorded for confidential reasons. Over the past few years the Chinese Government has restricted the amount of its tungsten ores which can be offered on the world market, favouring instead the export of value-added downstream tungsten materials and products.

Industry Developments

Metallic Minerals Limited's **Wolfram Camp** W-Mo project, 90km west of Cairns in Qld, has been under care and maintenance since late 2008. The deposit has total resources of 1.42Mt grading 0.6% WO₃ and 0.12% Mo

comprising 0.78Mt grading 0.56% WO₃ and 0.13% Mo in Indicated Resources and 0.64Mt grading 0.65% WO₃ and 0.11% Mo in Inferred Resources. The company's 76% owned-subsiidiary, Planet Metals Limited, has commenced studies into enhancing the run of mine pre-concentrate in order to improve the mill-feed grade.

Vital Metals Limited released an updated resource for its **Watershed** scheelite project, 150km northwest of Cairns, Qld, of 15.1Mt at an average grade of 0.46% WO₃ using a cut-off grade of 0.10% WO₃, for 69 300 tonnes of contained WO₃. The company has completed a full Environmental Impact Study, which has been accepted by the Queensland Environmental Protection Agency. However, the decline in tungsten prices to below US\$200/metric tonne unit (mtu) and the strengthening of the Australia dollar relative to the US dollar have impacted on the project's economic viability, causing the company to consider its options.

During 2009, Icon Resources Ltd completed its scoping study of an expanded open cut and longer-term underground mining proposal for its **Mount Carbine** project, about 130km northwest of Cairns, Qld. The company has commenced bulk metallurgical testing of the tailings and waste ore material accumulated during earlier mining operations. It proposes to rework the 2Mt of tailings commencing in early 2011 to produce around 50 tonnes per month of low-grade mixed concentrate for approximately 2 years. The company plans to commence production from the hard-rock project in 2013. The Mount Carbine project has Inferred Resources of 1.05Mt with an estimated recovered grade of 0.1% WO₃ in the old Mount Carbine open-cut mine, which closed down in 1987, and an Inferred Resource of 9.6Mt averaging 0.2% WO₃ beneath the mine.

The Dolphin Joint Venture, between King Island Scheelite and Chinese Hunan Nonferrous Metals Corporation, was proceeding with detailed designed and costing studies into the redevelopment of the former **King Island** scheelite mine, located near Grassy, on southeast King Island, off Tas. The redevelopment involves re-opening the former Dolphin underground mine, constructing a processing facility based on whole-ore-flotation with a 300 000 tonnes per annum (tpa) capacity to produce 3300tpa of 65% WO₃ concentrate. King Island Scheelite reported Indicated Resources for Dophin and Bold Head, at a cut-off grade of 0.25% WO₃ as 8.42Mt averaging 0.95% WO₃, and 2.3Mt averaging 0.73% WO₃, respectively, for a combined total of 96 780 tonnes of contained WO₃.

Venture Minerals Limited has completed a scoping study on its **Mount Lindsay** project, 125km from Burnie in northwest, Tas. The study concluded that the project could generate cash revenue in excess of \$700 million from a mining operation of 4 million tonnes per year (Mtpa) over a 7-year mine life. The estimated capital cost for the operation would be about \$255 million. As part of its pre-feasibility study, the company upgraded the Inferred Resources for the Mount Lindsay deposit to 36Mt averaging 0.2% Sn and 0.09% WO₃ (based on a cut-off grade of 0.2% Sn equivalent). This resource includes a stand-alone inferred tungsten resource of 5Mt averaging 0.4% WO₃ (based on cut-off grade of 0.15% WO₃). About 93% of the tungsten resources occur within 200m of the surface.

Thor Mining PLC has reported total Proved and Probable Reserves of 2.21Mt grading 0.47% WO₃ and 0.21% molybdenum disulphide (MoS₂) for its **Molyhil** W-Mo project, 250km northeast of Alice Spring, NT. The company has an off-take agreement with CITIC Australia Trading Limited, one of China's largest state-owned companies, which commits CITIC to take all of the Mo and W concentrates produced from the project. The company has scaled back activities at the Molyhil project because of the decline in the international price for Mo.

Hazelwood Resources Ltd has completed an integrated pre-feasibility study incorporating its **Big Hill** tungsten deposit, about 220km northwest of Newman, WA, and a ferrotungsten (FeW) project in Vietnam. Asia Tungsten Products Company Ltd (60%-owned by Hazelwood Resources Ltd) is constructing a FeW plant in the Vihn Bao district near the Port of Haiphong in northern Vietnam.

The study envisages a 12-year mine life based on processing 2.3Mtpa of ore through a conventional gravity separation circuit, producing up to 200 000mtu of concentrates per year (up to 1.6 million kilogram of W). Total capital costs for the development of Big Hill are estimated to be about \$112 million. The study assumes an average life of mine concentrate price of US\$225/mtu. The company expects construction to begin in 2011 with production commencing in 2012.

Stage one of the FeW plant in Vietnam is expected to produce approximately 2.4 million kilograms of contained W in the form of 80% grade ferrotungsten commencing in early 2011. Stage two, involving the construction of a second furnace, would be commissioned in 2012, increasing capacity to approximately 4.8 million kilograms of contained tungsten. This expansion will require the development of Big Hill to provide additional feedstock for

the planned stage 2 expansion. At full capacity, the plant will be the largest producer of FeW outside of China, accounting for approximately 25% of global demand for the product.

The Big Hill project is expected to provide about 33% to 66% of the total feedstock for the FeW project.

Uranium

Aden McKay (aden.mckay@ga.gov.au)

Major uses for uranium (U) 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.

Despite the economic impacts of the global financial crisis in the latter part of 2009 and early 2010 there was continued growth in the nuclear electricity industry in many countries. By mid 2010 there were 440 nuclear power plants operating in 30 countries, providing 14% of the world's electricity production (source: World Nuclear Association). A further 58 new plants were under construction, 15 more than at January 2009. Twenty-three of the new plants are being built in China where the government has ambitious plans for future expansion of its nuclear electricity generating capacity. Worldwide a further 152 plants are planned (108 at January 2009) including 39 planned in China, 20 in India, which in recent years has engaged in world civil nuclear fuel cycle activities, 14 in the Russian Federation, 12 in Japan and four in the United Arab Emirates which currently has no nuclear power reactors.

The current growth in nuclear power is a reflection of changing national policies on electricity generation. Several countries which had nuclear phase-out policies have reversed them in the past few years or are modifying their plans (Sweden, Belgium, Spain, Germany). Some countries have returned to a pro-nuclear position (the U.K., the USA, Italy) after lengthy government studies of future electricity requirements. Several other countries which have no nuclear power are planning to building nuclear plants (United Arab Emirates, Turkey, Poland, Jordan). In the USA, which has the largest number of nuclear power plants, construction commenced during 2009 on the first reactor to be built in the USA in more than 20 years.

The nuclear power industry has been developing and improving reactor technology for more than five decades. The new 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, although none have been built and they are unlikely to be operational before 2020¹⁴. 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% U²³⁵ and 99.3% U²³⁸. Commercial light water reactors use only U²³⁵ to generate electricity because it undergoes natural fission. Generation IV reactors will also 'burn' the U²³⁸ 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.

The technology and design of Generation IV reactors is 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 U²³⁸ and plutonium, as well as all the U²³⁵; and using spent fuel from current commercial reactors,
- greater fuel 'burn up', and
- 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, or the 'once through' fuel cycle. This will

¹⁴ World Nuclear Association, July 2009. Advanced Nuclear Power reactors. <http://www.world-nuclear.org/info/inf08.html>

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 wastes¹⁵.

Uranium spot market prices fell from US\$50 a pound (lb) for uranium oxide (U₃O₈) in January 2009 to US\$45 a lb by the end of 2009, but by October 2010 it had recovered to US\$48 a lb.

Resources

Geoscience Australia prepares estimates of Australia's uranium (U) resources within categories defined by the Organisation for Economic Cooperation and Development (OECD) 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 resulting from mining and milling have been deducted (Tables 8 and 9).

Table 8. Australia's uranium resources at December 2009 (reported under corresponding categories of NEA/IAEA and Australian national schemes).

National Scheme	NEA/IAEA Scheme	Tonnes U recoverable (December 2009)
Economic Demonstrated Resources (EDR)	Reasonably Assured Resources (RAR) recoverable at less than US\$80/kilogram (kg) U	1 223 000
Paramarginal Demonstrated Resources	RAR recoverable at US\$80–130/kg U	11 000
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	518 000
Paramarginal Inferred Resources	Inferred Resources recoverable at US\$80–130/kg U	46 000
Submarginal Inferred Resources	Inferred Resources recoverable at US\$130–260/kg U	3000

Australia's Economic Demonstrated Resources (EDR) at December 2009 were estimated to be 1.223 million tonnes U, which represented an increase of 5% on the estimates for December 2008 (1.163 million tonnes U). This was mainly the result of increase in resource estimates for the Olympic Dam deposit in South Australia (SA) and smaller increases at the Four Mile deposit (SA).

Australia had an additional 518 000 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 area of the Olympic Dam deposit.

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 Northern Territory (NT)
- Kintyre and Yeelirrie in Western Australia (WA).

¹⁵ 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 9: Uranium resources in States and the Northern Territory at December 2009.

	RAR recoverable at <US\$80/kg U Tonnes U	Inferred Resources recoverable at <US\$80/kg U Tonnes U	Total Resources Tonnes U	Percentage of Australia's Total Resources
South Australia	943 780	416 923	1 360 703	78%
Northern Territory	180 208	55 025	235 233	14%
Western Australia	69 305	35 631	104 937	6%
Queensland	30 054	10 568	40 622	2%
New South Wales	0	0	0	-
Victoria	0	0	0	-
Tasmania	0	0	0	-
Australia Total (rounded)	1 223 000	518 000	1 741 000	100%

Accessible EDR

Approximately 9% of uranium Economic Demonstrated Resources (EDR) is inaccessible for mining. All uranium deposits in Queensland (Qld) remain inaccessible because current State Government policy prohibits uranium mining. Applications for new mine developments in the NT are subject to approval by the Australian Government Minister for Resources, Energy and Tourism. In the NT, inaccessible resources 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

Joint Ore Reserve Committee (JORC) Code reserves comprise total uranium resources in Proved and Probable Ore Reserves as defined in the JORC Code. In 2009, JORC Code reserves of 307 000 tonnes U (recoverable) account for approximately 27% of accessible EDR.

World Ranking

Australia has the world's largest resources of uranium in Reasonably Assured Resources (RAR) recoverable at less than US\$80/kg U (equates to EDR). Australia's RAR recoverable at less than US\$80/kg U of 1.223 million tonnes U at December 2009 represents 46% of world resources in this category based on the latest estimates¹⁶ for other countries. Other countries with large resources include Canada with 13%, Kazakhstan 9%, South Africa 6% and the Russian Federation 4%.

Olympic Dam is the world's largest uranium deposit. Based on ore reserves and mineral resources reported by BHP Billiton as at June 2009, Geoscience Australia estimated that the deposit contains approximately one third of the world's total resources in RAR recoverable at less than US\$80/kg U.

Exploration

Uranium exploration expenditure in 2009 was \$179.6 million¹⁷ which was a decrease of 19% on the record level of expenditure attained in 2008 (\$220.5 million). The majority of expenditure was in SA (38%), followed by WA (25%), the NT (24%) and Qld (13%). Uranium exploration expenditure in Australia increased progressively from 2003 to reach a peak level in 2008. This was in response to the significant increases in spot market uranium prices, which increased over the same period to a peak in July 2007 and subsequently declined through 2008 and 2009.

¹⁶ latest estimates for other countries as reported in 'Uranium 2009: Resources Production and Demand'. OECD Nuclear Energy Agency and International Atomic Energy Agency. Paris

¹⁷ ABS Mineral and Petroleum Exploration, March quarter 2010



Beverley in situ recovery uranium mine, South Australia (Heathgate Resources)

Industry developments

SOUTH AUSTRALIA

BHPBilliton continued a major drilling program to explore for southern extensions of the **Olympic Dam** deposit.

Quasar Resources announced the discovery two new zone of sandstone type uranium deposits called **Pepegoona** and **Yadglin** deposits, which respectively are eight kilometres (km) north and 10km north northeast of Beverley mine.

Rex Minerals announced that drilling at the **Hillside** prospect on the Yorke Peninsula west of Adelaide intersected high grade uranium-copper mineralisation in skarns and altered basement rocks of the Gawler Craton.

Crescent Gold intersected low grade mineralisation at its **Big Lake** prospects in sandstones immediately overlying the Big Lake oil and gas field in the Cooper Basin in northeast SA. This is greenfield exploration in which the company acknowledged that its decision to explore in this area was based on recent research by Geoscience Australia. That research discussed the role that hydrocarbons appear to have played in the formation of large sandstone hosted uranium deposits and highlighted the potential for the discovery of similar deposits in Australia.

NORTHERN TERRITORY

In late 2008, Thundelarra Exploration Ltd discovered the **Thunderball** deposit, near Hayes Creek, 140km southeast of Darwin. Mineralisation occurs as disseminated to massive uraninite in sheared carbonaceous shales and chert and tuffaceous siltstones of the Pine Creek Orogen. The deposit comprises two sub-parallel zones, drill intersections in the lower zone average 6.6 metres (m) at 0.79% U_3O_8 and the upper zone averages 5.5m at 0.08% U_3O_8 . Drilling commenced at two other uranium prospects in the area, the **Corkscrew** and **Bella Rose** prospects which are 3.5km and 6km respectively southwest of Thunderball.

Rum Jungle Uranium Ltd identified uranium mineralisation associated with oxide copper on its **Mount Bundy** project 90km southeast of Darwin. Host rocks are hematite quartz breccias of the Koolpin Formation.

NuPower Resources reported drill intersections from the **Eva** uranium-gold project in the Murphy Inlier close to the Qld border. Near surface intersections included 27m at 0.77% U_3O_8 and 5.1 grams per tonne Au.

In October 2008, the Cameco Australia Pty Ltd—Paladin Energy Ltd Joint Venture was granted an Exploration Licence over **Angela-Pamela** deposits, 25km south of Alice Springs. Exploration drilling commenced on the Angela deposit in May 2009 and, during the year, a total of 103 exploration drillholes and eight large diameter geotechnical drillholes were completed. Amalgamation of historical drillhole data (Uranerz Australia Pty Ltd between 1972 and 1983) with drilling finished in 2009 and early 2010, was in progress in order to prepare an initial resource estimate.

QUEENSLAND

Paladin Energy (and joint venture partners) continued exploration drilling and resource evaluation on several uranium deposits in the Mount Isa region, including at the **Valhalla, Skal, Andersons, Bikini, Watta, Duke-Batman** and **Honey Pot** deposits. These are in a general region between 10km and 80km north of Mount Isa. These deposits are in albite-carbonate-hematite breccias and mylonite rocks which are part of the Eastern Creek Volcanics. Revised estimates of resources are summarised in the Industry Developments section below. The Oldin uranium prospect, 500m north of Valhalla, was discovered by exploration drilling during 2009 and exploration commenced at the Joker prospect, 5km south of Duke Batman deposit.

WESTERN AUSTRALIA

Energy Metals Australia Ltd and other companies continued exploration in Cenozoic sands and peat of the Gunbarrel Basin overlying eastern margins of Yilgarn Craton. **Mulga Rock** and **Double 8** deposits are in this area.

PRODUCTION

Production for 2009 from Australia's three uranium mines were, Ranger 5244 tonnes U₃O₈, Olympic Dam 3485 tonnes U₃O₈ and Beverley in situ recovery operations 688 tonnes U₃O₈ for a total Australian production of 9417 tonnes U₃O₈ (7985 tonnes U), 5% less than during 2008. Australia, with 16% of world uranium production in 2009, is the world's third largest producer after Kazakhstan and Canada.

Total world uranium production in 2009 was 50 772 tonnes U, an increase of 15% compared with 2008. Most of the increased production is attributable to significant growth in Kazakhstan's output, which rose 62% from 8521 tonnes U in 2008 to 14 020 tonnes U in 2009, and Canada which rose 13% to 10 173 tonnes U in 2009. Uranium requirements in 2009 exceeded uranium production by approximately 17 800 tonnes U.

EXPORTS

Exports in 2009 were 9339 tonnes U₃O₈ (7919 tonnes U) valued at \$1070 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. Receiving countries must be a party to and comply with the Treaty on the Non-Proliferation of Nuclear Weapons, have a bilateral safeguards agreement with Australia and, in the case of non-nuclear weapon States, have an Additional Protocol, which ensures the International Atomic Energy Agency has access to and inspection rights in the recipient country. These requirements apply also to third party States that may be involved in processing and transshipment of the material.

Australian mining companies supply uranium under long-term contracts to electricity utilities in the 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): BHP Billiton proposed a major expansion of the Olympic Dam operation 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 of refined copper, 19 000 tonnes of U₃O₈, 800 000 ounces of gold and 2.9 million ounces of silver. The capacity of the existing underground mine will be increased to approximately 20Mtpa by 2015. It is planned that the smelting operation will produce 350 000 tonnes per annum (tpa) of refined copper. An additional 1.6Mtpa of copper concentrates containing significant levels of uranium will be exported for further processing overseas.

The Environmental Impact Statement (EIS) for Olympic Dam Expansion was released for public comment in May 2009. The Supplementary EIS (response document) is planned for release in late 2010. Government decisions on the project are to be made in 2011.

Mine production for 2009 was reduced following damage to the haulage system in the Clark Shaft on 6 October which resulted in the ore hoisting capacity being cut by about 75%. Following repairs, ore hoisting from the shaft resumed during the June quarter 2010 and the mine returned to full production.

During 2009 there was a significant increase in resources as a result of additional resources being delineated by drilling in the southern portion of the deposit. Total Mineral Resources increased by 5% from 2.335 million tonnes (Mt) contained U₃O₈ at June 2008 to 2.452Mt contained U₃O₈ at June 2009.

BHP Billiton's estimates of ore reserves and mineral resources are shown in Table 10.

Table 10. Olympic Dam mineral resources and ore reserves (JORC Code) at June 2009
(Source: BHP Billiton Annual Report 2009).

	Million tonnes	Copper %	U ₃ O ₈ kg/t	Gold g/t	Silver g/t
Total resources* Measured + Indicated + Inferred	9080	0.87	0.27	0.32	1.5
Total reserves	589	1.81	0.59	0.66	3.36

* Mineral Resources includes ore reserves

Ranger mine (NT): Total Measured+Indicated+Inferred Resources at Ranger decreased by 7216 tonnes contained U₃O₈ during the year to 108 152 tonnes U₃O₈ as a result of updates of the resource model and also to conversion of resources to reserves. Of the 108 152 t U₃O₈, around 34 000 tonnes is within the Ranger 3 Deeps deposit which is adjacent to the current operating pit.

Energy Resources of Australia continued studies on development of a heap leach facility for extraction of up to 20 000 tonnes U₃O₈ contained in low grade mineralised material, both in situ and in stockpiles. An EIS is expected to be submitted in late 2010 and will be assessed by the Northern Territory Government on behalf of the Australian Government under a bilateral agreement.

Detailed studies continued into construction of an exploration decline for underground drilling to further evaluate the extent of Ranger 3 Deeps ore zone. A final decision on the decline is expected in 2010.

Beverley in situ recovery (ISR) mine (SA): Heathgate Resources operates the Beverley mine between the North Flinders Ranges and Lake Frome, approximately 300km northeast of Port Augusta. Uranium production has declined in recent years as the company mines the remaining resources within the Beverley mining lease. During 2009, production was mainly from old wellfields, some of which closed several years ago. The company re-activated many of these old wellfields from where additional uranium was produced. Exploration is planned in areas south of the mining lease boundary.

Four Mile ISR project (SA): In July 2009, the Australian Government approved the Four Mile ISR project based on an assessment of the environmental impacts of the project under the *Environment Protection and Biodiversity Conservation Act 1999 (EPBC)*. However, in October 2009, Alliance Resources (25% owners of the project) issued legal proceedings against the project operator Quasar Resources (75% owners) which is wholly owned by Heathgate Resources. As a result, the South Australian Government is unable to issue a mining lease for the project until the legal issues are resolved and Native Title Mining agreement is registered by the government. When this is resolved it is proposed that an ion exchange plant will be built at Four Mile and the resin will be taken 8km by truck to the Beverley plant for recovery of uranium.

Beverley North ISR project (SA): In 2009, Heathgate Resources discovered two new uranium deposits, the Pepegoona deposit, 12km north of Beverley mine and Yadglin deposit, 16km north-northeast of Beverley. The company proposes to mine Pepegoona by ISR methods and use the existing Beverley plant to recover uranium from mining solutions. This is referred to as the Beverley North project and it was being assessed under the EPBC Act and compilation of a Public Environment Report commenced. The company has applied for an extension of the Beverley mining lease to the north over these new discoveries. Exploration drilling continued in the area west of the Pepegoona deposit.



Production well at Beverley in situ recovery uranium mine, South Australia (Heathgate Resources)

Honeymoon ISR mine (SA): Construction of the solvent extraction plant and water treatment facilities for Honeymoon ISR operations continued. Production is expected to commence in early 2011 at 400 tonnes U_3O_8 a year.

Oban ISR project (SA): Curnamona Energy announced an initial Inferred Resource for the Oban deposit 65km north of Honeymoon mine of 8.2Mt averaging 260 parts per million (ppm) U_3O_8 for 2100 tonnes contained U_3O_8 . Mineralisation is in lower sands of the Eocene Eyre Formation at depths of 80m to 90m below the surface. These sands contain carbonaceous material and pyrite, and there are lignite interbeds. 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 propose to mine the Yeelirrie deposit, 70km southwest of Wiluna in WA. Uranium mineralisation occurs in calcretes within a paleochannel and the deposit is at shallow depths down to 15m below surface. Ore ranges from 1m to 7m thick. The proposal is to mine 3 to 4Mt of calcrete ore a year from several shallow open pits for a planned annual production of 4600 tonnes of yellowcake $UO_4 \cdot 2H_2O$ (equivalent to 3500 tonnes U_3O_8 per year). Yeelirrie currently has total resources of 52 500 tonnes U_3O_8 and is Australia's second largest undeveloped uranium deposit. BHP Billiton produced an Environmental Scoping Document for the Yeelirrie EIS and the environmental impacts will be assessed by the Western Australian Government under a bilateral agreement with the Australian Government.

Wiluna project (WA): comprises two shallow (less than 8m deep) calcrete hosted deposits, Lake Way and Centipede, which are 15km south and 30km south respectively from Wiluna. Lake Way has Inferred Resources of 10.53Mt averaging 543ppm U_3O_8 (5714 tonnes of contained U_3O_8) and Centipede has total Measured+Indicated+Inferred Resources of 9.7Mt averaging 554ppm U_3O_8 (5355 tonnes of contained U_3O_8). In early 2010, Toro Energy Ltd commenced work on an Environment Review and Management Plan which will be the basis for environmental assessment of the project by both the Western Australian and Australian Governments. In April 2010, the company commenced mining a 45 000 tonne evaluation pit at the Centipede deposit to increase confidence in the resource estimates and in the proposed mining method. It is planned to use the ore for metallurgical testwork. Two options for processing the calcrete ores being considered are alkaline heap leaching and agitated alkaline leaching in tanks.

MegaUranium Ltd received approval from the Western Australian Department of Mines and Petroleum to excavate two test pits about 40m long by 25m wide and 5m deep at the company's **Lake Maitland** project in WA as part of a feasibility study. The company also intends to undertake an exploration drilling program to search for extensions to the known resource.

In Qld, Paladin Energy (and joint venture companies) carried out resource definition drilling at **Valhalla** 40km northwest of Mount Isa and the **Skal** deposits 32km north of Mount Isa as well as at the **Bikini, Andersons Watta, Duke Batman** and **Honey Pot** deposits. Updated resources estimates for Valhalla and Skal were (Table 11):

Table 11. Valhalla and Skal Mineral Resources at December 2009

(Source: Paladin Energy Ltd. Annual Report 2010).

Total Measured and Indicated Resources			Inferred Resources			
Mt	Grade ppm U ₃ O ₈	tonnes U ₃ O ₈	Mt	Grade ppm U ₃ O ₈	tonnes U ₃ O ₈	
Valhalla	31.19	873	27 230	5.2	859	4494
Skal	4.3	575	2458	8.4	491	4129

Mineralogical investigations and metallurgical testwork continued and a process flowsheet for treatment of Valhalla ore was developed.

Latest resource estimates for Andersons, Bikini, Watta, Duke Batman and Honey Pot deposits can be viewed on the Paladin website. (Provide a link on Paladin website to: http://media.corporate-ir.net/media_files/irol/17/176316/2010_annual_report.pdf)

Energy Metals Ltd reported completed an infill drilling program during 2009 at the **Bigrlyi** deposit 300km northwest of Alice Springs, NT. Revised estimates for the deposit were reported as Indicated Resources of 4.7Mt at an average grade of 1316ppm U₃O₈ representing 6100 tonnes of contained U₃O₈ and Inferred Resources of 3.4Mt at an average grade of 1202ppm U₃O₈ representing 4000 tonnes contained U₃O₈. Large diameter cored holes for metallurgical test works were completed.

Other developments

Geoscience Australia finalised a *National In Situ Recovery Uranium Mining Best Practice Guide*. http://www.ret.gov.au/resources/Documents/Mining/10-4607_in%20situ%20uranium_31May.pdf

The investigations were carried out 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. The guide was approved by both the Minister for Resources and Energy and the Minister for Environment.

Vanadium

Alan Whitaker (alan.whitaker@ga.gov.au)

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, the desulphurisation of sour gas and oil and in the development of fuel cells and low charge time, light weight batteries.

Vanadium is sold as vanadium pentoxide (V₂O₅), or less commonly as vanadium trioxide (V₂O₃) and as an alloy of iron and vanadium, most commonly as FeV80 which has 80% contained vanadium, or as FeV50.

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 rises and equally sharp declines over short periods. Historically, prices have ranged from US\$1.30 a pound V_2O_5 to more than US\$20 a pound. Average prices fell from US\$14.75 a pound V_2O_5 in 2008 to US\$6.00 a pound in 2009 in response to the impacts of the global financial crisis and the decreased demand for vanadium from the steel industry in many countries.

Resources

Australia's Economic Demonstrated Resources (EDR) of vanadium increased by 53% in 2009 to 2673 kilotonnes (kt). Australia's EDR of vanadium has increased progressively over the past three years with growth in resources over this period at Balla Balla deposit mid-way between Karratha and Port Hedland in Western Australia (WA), Barambie 80 kilometres (km) north of Sandstone, WA, Speewah Dome in the east Kimberly, WA, and Bigrlyi located 390km northwest of Alice Springs, in the Northern Territory (NT) and at Julia Creek in north Qld.

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. These secondary sources are able to rapidly increase or decrease output in response to price trends.

World Ranking

China, the Russian Federation and South Africa have the world's largest economic resources of vanadium (based on US Geological Survey Mineral Commodity Summary 2010). It is not possible to determine Australia's ranking, but Geoscience Australia data indicates that Australia has the world's fourth largest resources.

Exploration

Data on exploration expenditure for vanadium are not available although exploration continued at the Balla Balla, Barambie, Victory Bore, Gabanintha and Speewah Dome deposits (WA) and at the Bigrlyi and Mount Peake deposits (NT).

Production

There was no production of vanadium in Australia during 2009 and only a limited period of mining at Windimurra (WA) in 2008. 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 2009 was in China (37%), South Africa (35%) and Russia (26%).

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 ferrovandium and 1000tpa 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. In December 2009, Atlantic Limited acquired an option to buy into the project and progress development back into production. A subsequent capital raising and agreement will allow the company to acquire full control of the project.

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 Proved Ore Reserves of 40.7Mt grading at 0.47% V_2O_5 and Probable Ore Reserves of 57.1Mt 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 per 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

110km 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 Proved Ore Reserves being 180.4Mt grading at 0.63% V₂O₅, 14.0% TiO₂, and 45.2% Fe, and Probable Reserves being 26.9Mt grading at 0.62% V₂O₅, 13.5% TiO₂, 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 65.2Mt grading at 0.82% V₂O₅, 17.3% TiO₂ and 49.2% Fe₂O₃.

Niplats Australia Limited released initial resource figures for the **Central Prospect** at its **Speewah Dome** project in the east Kimberly district, 100km south of Windham, northern WA. With a cut-off grade 0.23% V₂O₅, the Central Prospect consists of an Indicated Resource of 334Mt grading 0.32% V₂O₅, 15.1% Fe and 2.1% Ti, and an Inferred Resource of 517Mt at 0.32% V₂O₅, 14.8% Fe and 2.1% Ti. Resource drilling was undertaken also at the adjacent **Buckman** and **Red Hill** prospects hosted by the same igneous intrusion.

Yellow Rock Resources Limited released an updated resource estimate in January 2009 on its **Gabanintha** vanadium-iron-titanium project, 43km southeast of Meekatharra, WA. Based on a cut-off grade of 0.35% V₂O₅, the project comprises a Measured Resource of 94.9Mt grading at 0.56% V₂O₅, 27% Fe, and 7.2% TiO₂, an Indicated Resource of 34.68Mt grading at 0.69% V₂O₅, 31.9% Fe, and 8.5% TiO₂, and an Inferred Resource of 21.9Mt grading at 0.74% V₂O₅, 33.9% Fe, and 9.0% TiO₂. 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) U₃O₈, the deposit contains Indicated Resources of 2.3306Mt grading at 1739ppm U₃O₈ and 2429ppm V₂O₅ and Inferred Resources of 5.231Mt grading at 1250ppm U₃O₈ and 2705ppm V₂O₅.

Zinc, Lead, Silver

Keith Porritt (keith.porritt@ga.gov.au)

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 100Mt 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 consequently attracts 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-leveling 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** makes 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 50 cent piece was the last coin in general use to contain silver (80% Ag, 20% Cu). Silver is mined and produced mainly as a co-product of 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 rose marginally in 2009. Total identified resources of zinc rose from 84Mt in 2008 to 85Mt in 2009, lead rose 2Mt to 55Mt and silver rose 9 kilotonne (kt) to 119kt.

ZINC

Australia's Economic Demonstrated Resources (EDR) of zinc at 58Mt accounts for around 25% of world economic resources and is the world's largest holding. The 5Mt increase in national EDR compared to 2008 is largely associated with the release of new resource statements for the George Fisher deposit in Qld and the Endeavor and Broken Hill deposits in NSW. Queensland continued to hold the largest resource with 34Mt, or 58% of national EDR, predominantly at the George Fisher, Mount Isa, Century and Dugald River deposits. The Northern Territory (NT) again had the second largest EDR with 16Mt, or 28% of national EDR, all at the McArthur River deposit. Following was NSW with 4Mt EDR, up from 2Mt in 2008 and mostly at the Broken Hill and Endeavor deposits. Then, Western Australia (WA) with 2Mt, mostly at the Golden Grove, Sulphur Springs and Jaguar-Bentley deposits. Total inferred zinc resources remained steady at 22Mt in 2009.

LEAD

Australia's EDR of lead increased by 4Mt in 2009 to 31Mt of contained lead and constituted 56% of Australia's total identified lead resources (55Mt). Australia also accounts for the largest share of world economic resources for lead at 36%. Queensland retained the top ranking with its EDR increasing from 17Mt in 2008 to 18Mt in 2009, which represents a 59% share of national EDR. The NT lead EDR ranks second with 7Mt or 24% of the national total, almost all of which is at the McArthur River mine. New South Wales recorded an increase in EDR from 1Mt in 2008 to 3Mt, largely because of an increase in reserves at Endeavor and Broken Hill. Australia's Paramarginal Demonstrated Resources of lead decreased by 2Mt to 5Mt, which is 9% of total Identified Resources, as more of the older resources are redrilled and re-estimated under the Joint Ore Reserve Committee (JORC) Code. Total inferred lead resources were largely unchanged in 2009 at 19Mt.

SILVER

EDR for silver is 70kt which is 16% of world economic resources. Queensland has 42kt or 60% of Australian EDR, mainly in the Cannington, Mount Isa, George Fisher, Dugald River and Century deposits. Most other silver EDR occurs in SA (11kt), the NT (7kt), NSW (6kt), WA (2kt) and Tas (2kt). In SA, most silver EDR is at Olympic Dam with some at Prominent Hill while in the NT silver EDR is nearly all at McArthur River. In NSW it is mostly at Broken Hill and Endeavor, while in WA it is predominantly at Golden Grove, Spinifex Ridge and Jaguar-Bentley.

Accessible EDR

All zinc, lead and silver EDR is accessible.

JORC Reserves

Of Australia's EDR of zinc, 33% occurs in the Joint Ore Reserve Committee (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 45 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, 35% occurs in the JORC Code ore reserves categories. For lead, the national EDR/production ratio is 54 years, but if the ore reserve/production ratio is used it is 19 years. For silver, JORC Code reserves account for around 37% of EDR and resource life is 43 years for EDR or 16 years for JORC Code reserves.

Exploration

In 2009, exploration spending on zinc, lead and silver was \$48 million, 64% lower than in 2008. The 2009 expenditure was 13% of total base metal expenditure of \$369 million compared to 18% in 2008. Expenditure on exploration for the three commodities made up only 2% of all mineral exploration which, excluding petroleum, was \$2 billion and compared to 5% in 2008. Western Australia, NSW and Qld were the focus of most of this exploration expenditure with WA accounting for \$13 million or 27% of all zinc, lead and silver exploration.

Production

The 2009 Australian mine production of zinc, lead and silver was 1.29Mt, 0.57Mt and 1.63kt respectively. Compared to 2008, production in 2009 was reduced by 15% for zinc and silver and by 12% for lead. The majority of production was from Qld which contributed 815kt, or 63% to national zinc production for 2009 (down 104kt on 2008) along with 408kt or 72% of lead (down 73kt) and 1.3kt or 82% of silver. Western Australia produced 90kt of zinc and 5kt of lead with both being below half of the 2008 production level because of the closure of the Pillara zinc-lead mine, preference for copper ore at Golden Grove and suspension of production at the Magellan lead mine. Elsewhere, NSW produced 108kt zinc (23% less than in 2008) and 80kt lead, the NT 167kt zinc and 37kt lead and Tas 90kt zinc and 28kt lead.

The Century zinc mine, which is located close to the Gulf of Carpentaria about 250 kilometres (km) north of Mount Isa in northwest Qld, ranks in the top few globally in zinc production. Century produced 361kt of zinc as metal-in-concentrate in 2009, which was 28% less than in 2008 because of an 11 week outage of a pipeline which transports concentrate to the port of Karumba. The Cannington mine, also located in northwest Qld, is the world's largest and lowest cost single mine producer of both silver and lead as well as a significant producer of zinc. Cannington produced 226kt of lead, 1kt of silver and 60kt of zinc in 2009. Also in Qld are Xstrata's Mount Isa mines which produced 324kt of zinc, 146kt of lead and 0.2kt of silver in 2009.

The value of Australia's exports of zinc concentrates and refined zinc in 2009 totalled \$1.8 billion, 22% less than the \$2.3 billion in 2008 and 1% of the value of total merchandise exports. Although the tonnage of zinc exports decreased by only 5% to 1.4Mt in 2009, the value of these exports was 22% lower than in 2008 because of lower zinc prices in 2009. The average price for zinc in 2009 was \$2233 a tonne, 10% lower than the average of \$2494 per tonne in 2008. However, the 2009 December quarter average price was 14% higher than for the December quarter in 2008.

Exports of lead totalled 646kt in 2009, up 7% on 2008. The value of the 2009 exports was 4% lower at \$1.65 billion compared to \$1.71 billion in 2008. The average price for lead was 18% lower at \$2376 a tonne compared to the average of \$2886 per tonne in 2008. However, lead prices were 12% higher when comparing December quarters. For silver, the average price was 9% higher at \$589 a kilogram (kg) compared to the average of \$559/kg in 2008 with a 24% December on December increase. The value of Australia's mine production of silver was \$1 billion in 2009, down 10% on 2008.

World Ranking

Based on United States Geological Survey (USGS) data for other countries, Australia has the world's largest economic resources of zinc (25%), lead (36%) and silver (16%). In terms of production, Australia ranks third for zinc after China and Peru, second for lead after China and fifth for silver after Peru, Mexico, China and Chile.

Industry Developments

Mount Isa and George Fisher (Qld): Mount Isa zinc-lead operations commenced production in 1931 and were acquired by Xstrata Plc in 2003. Operations currently comprise the George Fisher underground mine, the open cut mines of Black Star and Handlebar Hill, an eight million tonnes per annum (Mtpa) capacity zinc-lead concentrator, a lead smelter and a zinc filter plant. During 2009 there was extensive restructuring of Mount Isa operations, resulting in a 40% reduction in costs. The higher cost Handlebar Hill mine commissioned in 2008 was



Surface facilities Century zinc-lead mine, north Queensland (Minerals and Metals Group Ltd)

placed on care and maintenance for the first seven months of 2009, while zinc and lead prices were low and since then has been mined opportunistically. At Mount Isa, record production was achieved in 2009, despite a reduced workforce, reduced capital spending and record rainfall early in the year. The Mount Isa zinc-lead concentrator recorded throughput of 7.4Mt, a 22% increase on 2008 as a result of increased production from the high-grade George Fisher and large-scale Black Star operations. Black Star produced a record 3.4Mt, 51% higher than in 2008. Total Mount Isa zinc in concentrate production rose by 15% to 324kt in 2009, while lead in concentrate production declined by 10% to 126kt due to lower lead grades and silver was 24% lower at 7.8 million ounces (Moz). Together, the cost savings and increased zinc volumes contributed to a profit of \$192 million for Xstrata's Australian zinc operations, compared to a loss of \$54 million in 2008. Smelter production of lead in bullion of 146kt was 12% lower than in 2008, mainly as a result of a decrease in third-party concentrate supply. A feasibility study was conducted at the Black Star open cut, resulting in a \$133 million expansion proposal in March 2010, which potentially will extend the life of Black Star by four years to 2016 at current production rates. A feasibility study into an expansion of George Fisher began in 2009 following an 80% increase in reserves over the past four years from 33.6 to 60.6Mt with a combined zinc and lead grade of more than 13%. The proposed expansion will increase output from 3.5Mtpa to 4.5Mtpa.

Century (Qld): The Century mine is the world's second largest open pit zinc mine. Chinese unlisted Minerals and Metals Group (MMG) acquired the Century, Rosebery and Golden Grove mines, amongst others, in early 2009 as part of the solution to former owner, OZ Mineral's refinancing problems. During 2009 Century produced 361kt of zinc as metal in concentrate, 30% less than 2008. Production was significantly impacted by the failure in October of the underground pipeline transporting concentrate 304km from Century to the port at Karumba. This resulted in a 79-day production shutdown during which 1Mt of ore was stockpiled and routine maintenance work was brought forward, including work on the Semi-Autogenous Grinding (SAG) mill motor, ball mill motor and gearbox and primary crusher. Following a wet season discharge of water from overflowing sediment dams into Page Creek, which incurred a \$130 000 fine, MMG committed \$8 million for remediation and preventative works. Century commenced operation in 2000 and mine life currently is to continue to 2015. A \$6 million, 18-month exploration program has begun, exploring nearby leases for potential future ore supply.

McArthur River (NT): Production capacity was up from 1.8Mtpa to 2.5Mtpa in 2009. This was due to the completion of a \$37 million concentrator expansion in 2008, combined with the conversion from underground to open pit mining. Xstrata Zinc's optimisation initiatives reduced mine costs by 18% in 2009 compared to

2008. McArthur River mine was placed on care and maintenance during January and February 2009 pending expansion re-approval. In the 10 months of production possible in 2009, total ore milled was 2.1Mt, an increase of 3% on the 2008 annual total. Higher average head grades resulted in a 17% increase in zinc in concentrate for the year, at 166kt. Also produced were 37kt of lead and 1.5Moz of silver. The conversion to an open pit required the McArthur River to be re-channelled which was completed in time for the 2009 wet season. Associated with this development are a wide range of biodiversity management programs which monitor potential impacts on surrounding endangered species and the 385km river. The expansion allows the mine to continue operations for another 25 years.

Rosebery (Tas): In 2009, metal in concentrate produced was 89kt of zinc, 27kt of lead, 3kt of copper, 33 161 ounces of gold and 3Moz of silver. New owners, Minerals and Metals Group (MMG), recommenced a \$25 million ventilation project that includes a 1300 metre deep raise borehole ventilation shaft to support access to the deeper reaches of the underground mine. The project, originally planned for 2008, was put on hold when previous owner, OZ Minerals Limited, encountered financial difficulties. Deep exploration drilling is targeting new areas below the Rosebery orebody. Drilling also commenced on the Jupiter prospect to test a new mineralised horizon identified during 2008 exploratory drilling. Rosebery currently has a mine life beyond 2020.

Golden Grove (WA): The Minerals and Metals Group (MMG) Golden Grove zinc and copper operation consists of the Scuddles and Gossan Hill underground mines and the Scuddles processing plant. As part of measures taken to reduce costs, the Scuddles mine was put on care and maintenance in January 2009. In response to the weak zinc price a copper focused mine plan was implemented. This resulted in reduced zinc production for 2009 of 57kt compared to 140kt in 2008 and record copper production of 31kt, up from 18kt in 2008. Also produced were 29 095 ounces of gold (47 755 ounces in 2008) and 1Moz of silver (3Moz in 2008). All figures are for contained metal in concentrate. Failure of a SAG mill bearing in June had an impact on zinc production with the mill off line for four weeks. Guidance for 2010 is up to 32kt of copper and 85kt of zinc. Exploration was recommenced in 2009 with drilling targeting down-plunge extensions of the Scuddles and Gossan Hill ore bodies and testing of near-mine prospects south of Golden Grove. Expansion studies to investigate the addition of open pit copper mining also were recommenced. Work on an additional tailings storage facility with a 15-year life commenced in late 2009.

Broken Hill (NSW): In 2009 Perilya Limited operated with significantly reduced employee numbers and pursued a mine plan limited to the Southern Operations, accessing higher grade ore and a lower tonnage of 1.4Mtpa (1.6Mtpa in 2008) in response to low zinc and lead prices. Consequently, production was 70kt zinc (down 22% on 2008), 57kt lead (up 21%) and 1.8Moz silver (up 35%). All three figures are metal in concentrate. In November Perilya reported a 28% increase in ore reserves for its Broken Hill operation to 12Mt at 6% Zn, 4.5% Pb and 48 grams per tonne (g/t) Ag from a mineral resource of 21Mt at 9.4% Zn, 7.4% Pb and 92g/t Ag. These reserves provide for 10 years of production at the Southern Operations at up to 130kt of contained metal a year. Perilya's three main developments, North Mine, North Mine Deeps and the Potosi project remained on care and maintenance throughout 2009. Similarly, CBH Limited undertook minimal exploration activity at its nearby Rasp development in 2009, having placed it on care and maintenance in June 2008. Resources reported for Rasp in August of 16.5Mt at 6.6% Zn, 5.1% Pb and 89g/t Ag were a 225% increase in zinc and lead on the 2006 estimate. A study for a 0.75Mtpa project at Rasp with a 15-year mine life indicated an annual production rate of 48kt of zinc, 39kt of lead and 2.3Moz of silver. An initial two years at Rasp as a smaller-scale 0.42Mtpa mine was approved in January 2010. This will access high-grade remnant pillars within the main lode at an expected head grade of 8.8% Zn, 8.8% Pb and 209g/t Ag. This ore will be transported 500km east for processing at CBH's Endeavor mine near Cobar, NSW. From 2012, CBH plans to mine the undeveloped Western and Centenary lodes at Rasp and an onsite plant is to be constructed for processing the ore. In January 2010 CBH agreed to sell 50% of Rasp for \$57.5 million to its 28% shareholder, Japanese company, Toho Zinc Co Ltd, rejecting a takeover offer made by Belgium-based company, Nyrstar NV.

Endeavor (NSW): In 2009 CBH Resources Limited pursued a low-tonnage, high-grade mine plan at Endeavor to minimise cash outflows during a period of low zinc and lead prices. The mine operated at a rate of 0.42Mtpa in 2009 producing 32kt of zinc (47kt in 2008) and 17kt of lead (22kt in 2008). Endeavor recorded an operating loss of \$37 million for the 2008–09 financial year but returns have since improved. Planning commenced to increase production to 0.85Mtpa as metal prices return to sustainable levels. Accordingly, in late 2009 Endeavor's paste plant was recommissioned after being unused all year and drilling and mining activities associated with doubling the production rate were started. At 0.85Mtpa the mine life is estimated to be 10 years.

Angas (SA): Operations began at Terramin Australia Ltd's underground Angas mine in July 2008 at a setup cost of \$71 million. The mine reached nameplate production capacity of 0.4Mtpa in the second half of 2009. Production for 2009 was 15kt of zinc, 6kt of lead, 2251oz of gold and 0.2Moz of silver, all as metal in concentrate. Close location to infrastructure and fixed grid power helped offset low zinc and lead prices in 2009. Angas has reserves of 2.2Mt at 7.6% Zn and 2.9% Pb which are sufficient for a further five year operation at current production rates. Terramin is undertaking both near mine and regional exploration, including at many nearby historic mine sites which have not been the subject of modern exploration. A program of airborne geophysics also is planned to locate additional drill targets.

Mungana (Qld): Kagara Limited's zinc interests are centred on the Mount Garnet-Chillagoe region of north Qld and include mines at Mungana, Mount Garnet and Balcooma and three processing facilities. Copper, gold, silver and lead also is produced. Kagara restructured operations in 2009, focusing on higher margin orebodies at Mungana and Balcooma and increased copper production. Metal in concentrate production in 2009 across Kagara's north Qld operations was 38kt of zinc and 27kt of copper. Ore from Mungana and Balcooma is taken by truck to the polymetallic treatment plant at Mount Garnet. Flooding caused road closures for most of January and February and ore stockpiled at plants was processed throughout the closure. Mount Garnet underground mine commenced stoping in February 2009 producing ore at around 9% Zn which was blended with high grade Mungana ore of about 16% Zn and 2% Cu.

Jaguar—Bentley (WA): The Jaguar project consists of three high grade deposits, Jaguar, Teutonic Bore, and Bentley, located approximately 300km north of Kalgoorlie. Perth-based Jabiru Metals Limited began operations at Jaguar in 2007 and production in 2009 was 33kt of zinc and 10kt of copper from around 0.4Mtpa of ore. In late 2008, Jabiru discovered the Bentley deposit, 4km to the south and of a similar size to Jaguar. Exploration drilling was conducted at Bentley in 2009 resulting in an Indicated Resource of 1.7Mt grading 1.9% Cu, 12% Zn, 0.8% Pb, 0.8g/t of Au and 148g/t Ag. Drilling will continue in 2010 and a feasibility study will be conducted. A mining lease was granted for Bentley in February 2010 and production is planned for 2011 with ore being processed through the Jaguar concentrator.

Hellyer—Fossey (Tas): In June 2009, Bass Metals Limited finalised the purchase of the Hellyer processing plant, associated infrastructure and Hellyer mining lease for an initial \$4 million from Intec Limited with up to \$5 million to follow with production. During 2009, Bass conducted a feasibility study on the Fossey deposit it discovered in late 2007. In August 2009, an updated resource estimate was released of 0.8Mt grading at 9.9% Zn, 5.8% Pb, 0.4% Cu, 2.5g/t Au and 137g/t Ag, with 86% of the resource classed as indicated. In January 2010, Bass formally approved the Fossey development, commencing work on the decline and refurbishment of the Hellyer mill which has been on care and maintenance since September 2008. Under an off-take agreement Bass has committed 100% of zinc and lead concentrate to Nyrstar NV.

RESOURCE LIFE



Geologist at Prominent Hill mine, South Australia (OZ Minerals Ltd)

Resource Life

The continuing contribution of Australia's mineral resources to national economic performance in the medium and longer term will depend of the discovery and development of new good quality resources. To assist with an assessment of the future supply capability of identified resources, an indicator of resource life using ratios of Accessible Economic Demonstrated Resources (AEDR) to current mine production are provided in the commodity review chapters. Ratios of production to ore reserves published by companies 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 12 presents a comparison of the AEDR/production ratios as assessed from 1998 to 2009. During the 12 year period there has been a significant trend towards lower AEDR/production ratio for coal and iron ore, which are the nett result of major increases in production and reassessment of resources.

Table 12: Years of Accessible Economic Demonstrated Resources (AEDR) at the production level for the year (rounded to nearest 5 years)

Commodity	1998	2003	2008	2009
Bauxite	70	90	85	85
Black coal	180	110	90	100
Brown coal	630	440	490	470
Copper	40	50	85	95
Diamond	3	5	10	20
Gold	15	20	30	30
Iron Ore	100	60	70	70
Lead	30	30	40	55
Manganese ore*			20	20
Mineral sands				
ilmenite	70	85	85	110
rutile	75	90	55	70
zircon	60	50	55	70
Nickel	65	120	130	145
Silver	30	25	30	45
Uranium	105	80	125	140
Zinc	30	25	35	45

* 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 20 years at current rates of production), manganese ore (20), gold (30), zinc (45) and silver (45). 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. The full impact of the global financial crisis was felt in 2009 and many companies reduced mine production compared with 2008. The lower production has resulted in increases in resource life which reversed the historical trend of decreasing resource life for some commodities, including coal, copper, lead, ilmenite, rutile, zircon, nickel, silver and zinc.

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 continuously searching for mineral deposits which offer the most attractive returns on investment. Such returns are influenced not only by the quality of the resources (grade and tonnage) but also by the environmental, social and political factors, land access and the location and scale of the existing mining operations owned by the company.

The world financial crisis in 2008 exacerbated these factors and forced many companies to reassess their options for both existing and planned operations in Australia. In the case of black coal and iron ore, the initial impact of the world financial crisis caused some mining operations to scale back production, others delayed plans for expansion and some mines closed at the end of 2008. However, by mid 2009, recovery in mining operations and development plans were well under way for the affected commodities and this trend continued in 2010.

In the case of nickel, some multinational companies closed sulphide and lateritic nickel mines in WA and Tas and consolidated their operations at larger low cost mining operations, although not necessarily in Australia. This is a consequence of the dominance of large multinational mining companies in the world mining industry. Some of these companies are considering re-opening these mines in view of the world economic recovery and rebounding nickel prices in late 2009.

Although total copper production fell by 4% in 2009, production commenced at Prominent Hill (SA) and studies continued through the year into major development proposals at Olympic Dam (SA), Cadia East (NSW) and Ernest Henry (Qld). Several zinc-lead mines remained on care and maintenance throughout 2009. Of those that remained in operation most pursued a high-grade, lower tonnage plan, with reduced workforce and lower expenditure. Towards the end of 2009 several zinc-lead mines embarked on plans to increase tonnage, reopen infrastructure and recommence development or exploration in anticipation of a continuing recovery of zinc and lead prices through 2010.

Continuing increases in the price of gold since 2000 have maintained a high level of exploration expenditure for this commodity and resulted in a steady increase in Economic Demonstrated Resources (EDR). Average grades of the resources have fallen from 1.6 grams per tonne (g/t) in 2000 to 0.6g/t in 2009. Mine production has decreased over this period also, from 290 tonnes to 223 tonnes in 2009. As a result of exploration success, together with falling mine production, resource life for gold has increased from 17 years to 33 years during the past decade.

The scaling back of production at the Argyle diamond mine in response to a weak diamond market has largely contributed to the significant increase in resource life for Australia's diamond resources in 2009. In 2009, Argyle produced 98% of Australia's diamond production.

For heavy mineral sands operations, some producers closed down low grade ilmenite deposits in 2008 to concentrate on deposits which are more readily amenable to beneficiation, or have a higher content of zircon. However, sharply lower levels of production of ilmenite, rutile and zircon in 2009 due to the flow-on effects of the global financial crisis in late 2008 and early 2009 led to increases in resource life. Exports of ilmenite, rutile and zircon far outstripped production of these commodities in 2009 because of the recovery in world economy during the second half of 2009. A portion of these exports were from the draw down of stockpiles.

For Australia to maintain its position as a premier mineral producer and compete in the world market, it will require continuing investment in exploration to locate good quality resources and to upgrade known deposits as well as investment in metallurgical beneficiation processes to improve ore recovery levels.

EXPLORATION



Logging core at Cameby Downs coal mine Queensland (Syntech Resources Pty Ltd)

Exploration

Mike Huleatt (mike.huleatt@ga.gov.au)

Overview

Australian mineral exploration spending in 2008–09 fell by almost 10% to \$2223.9 million as the impact of the global economic crisis began to be felt. Of the total 37% was spent on the search for new deposits (greenfields exploration).

Figure 2. Australian mineral exploration expenditures by commodity in constant 2008–09 dollars (Based on ABS data deflated by Consumer Price Index series).

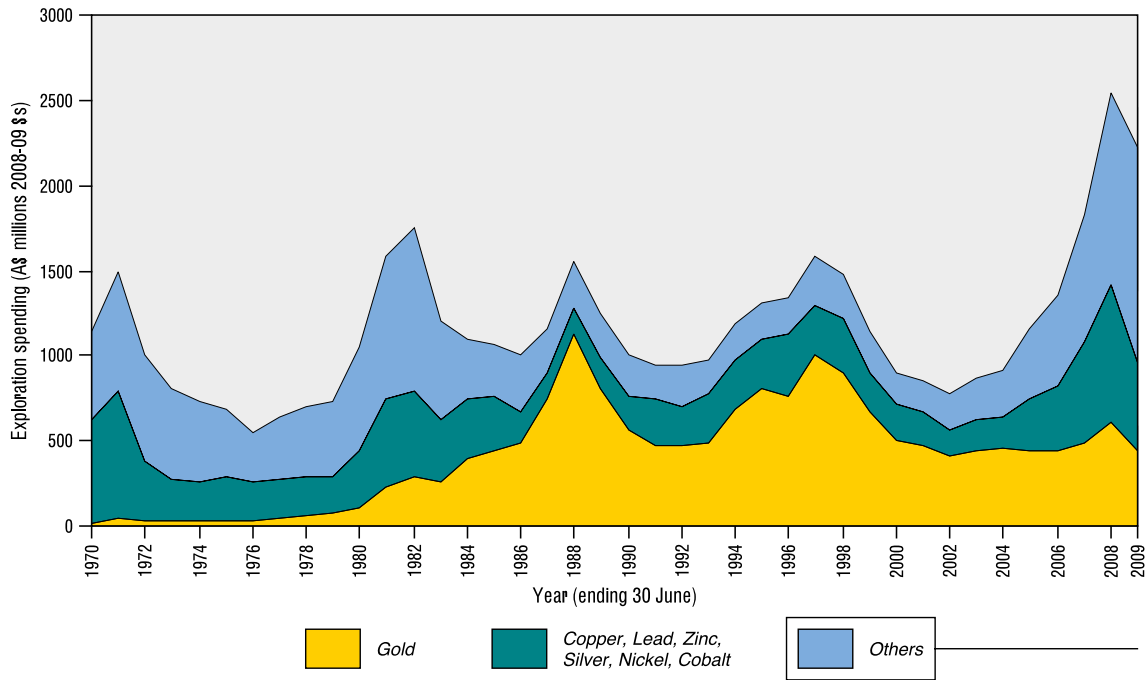
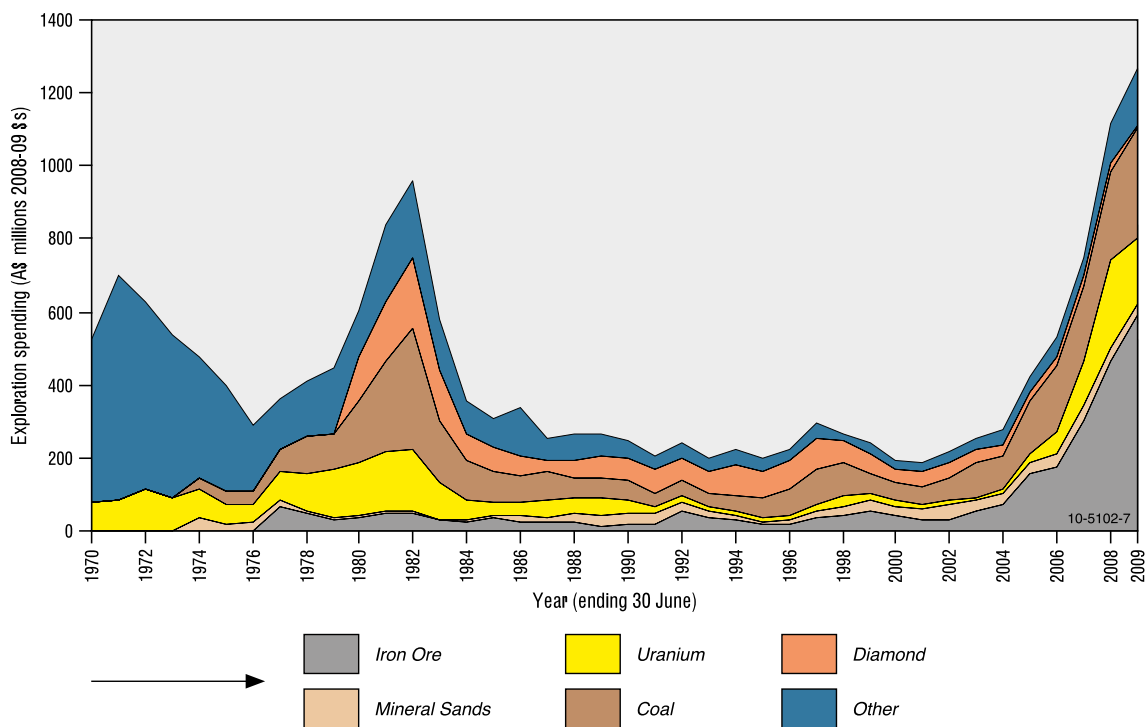


Figure 3. Australian mineral exploration expenditure, excluding gold and base metals, in constant 2008–09 dollars (Based on ABS data deflated by Consumer Price Index series).



Western Australia (WA) continued to dominate with 56% of Australian mineral exploration spending. Only the Northern Territory (NT) recorded an increase in expenditure during 2008–09 with 10% growth. All States recorded reduced spending.

Iron ore overtook gold as the principal commodity explored for and was a record \$588.7 million, an increase of 31% on 2007–08. In contrast, spending on gold fell by 26% to \$438.1 million and spending on the base metals, the previous largest target fell by 34% to \$519 million.

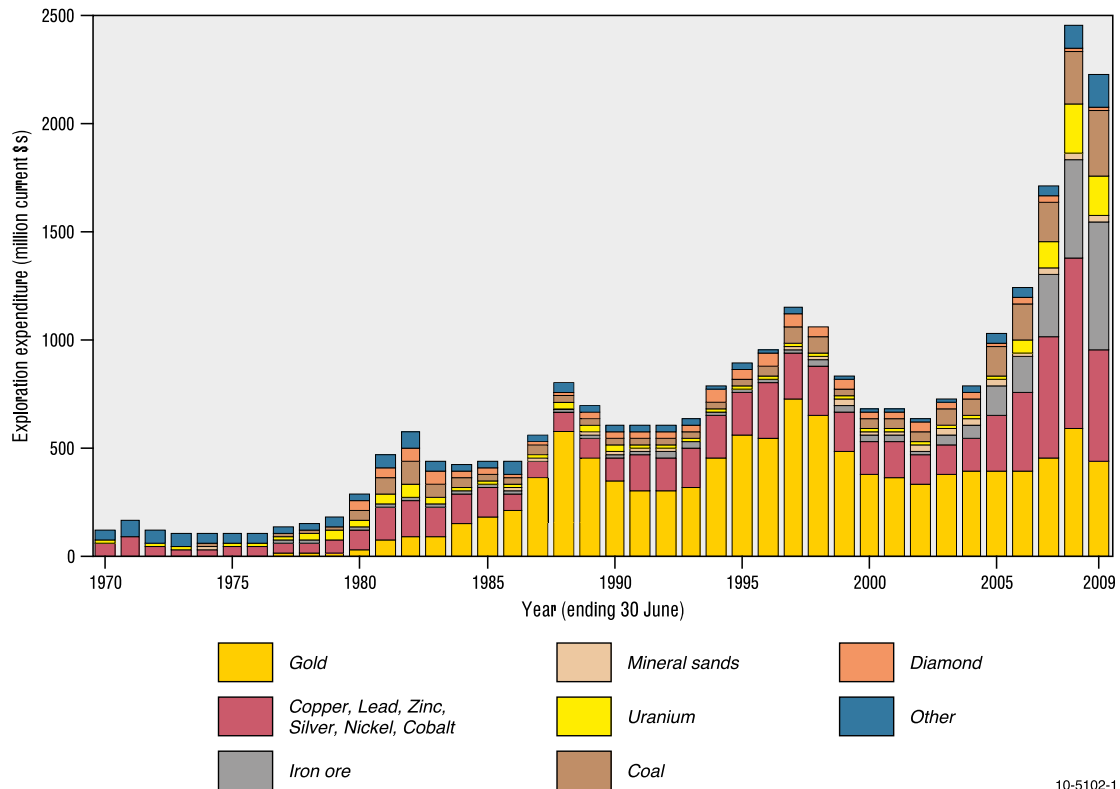
Review

2008–09 was a year of significant change in Australian mineral exploration as the impact of the world economic crisis registered although the growth of the Chinese economy helped mitigate the effects of the crisis. Exploration, however, again resulted in significant increases in resources at known deposits and a substantial number of drill intersections of economic interest. In marked contrast to many other countries, strong growth in Australian iron ore and coal exploration helped limit the reduction in total exploration spending to 10% compared to 2007–08.

The fall in Australian mineral exploration expenditure of 10% saw spending fall to \$2223.9 million in 2008–09 according to the Australian Bureau of Statistics (ABS). Although this was a significant reduction actual spending remained at historically high levels. In 2008–09 constant dollars, expenditure also remained at the second highest level on record (Figs. 2 and 3).

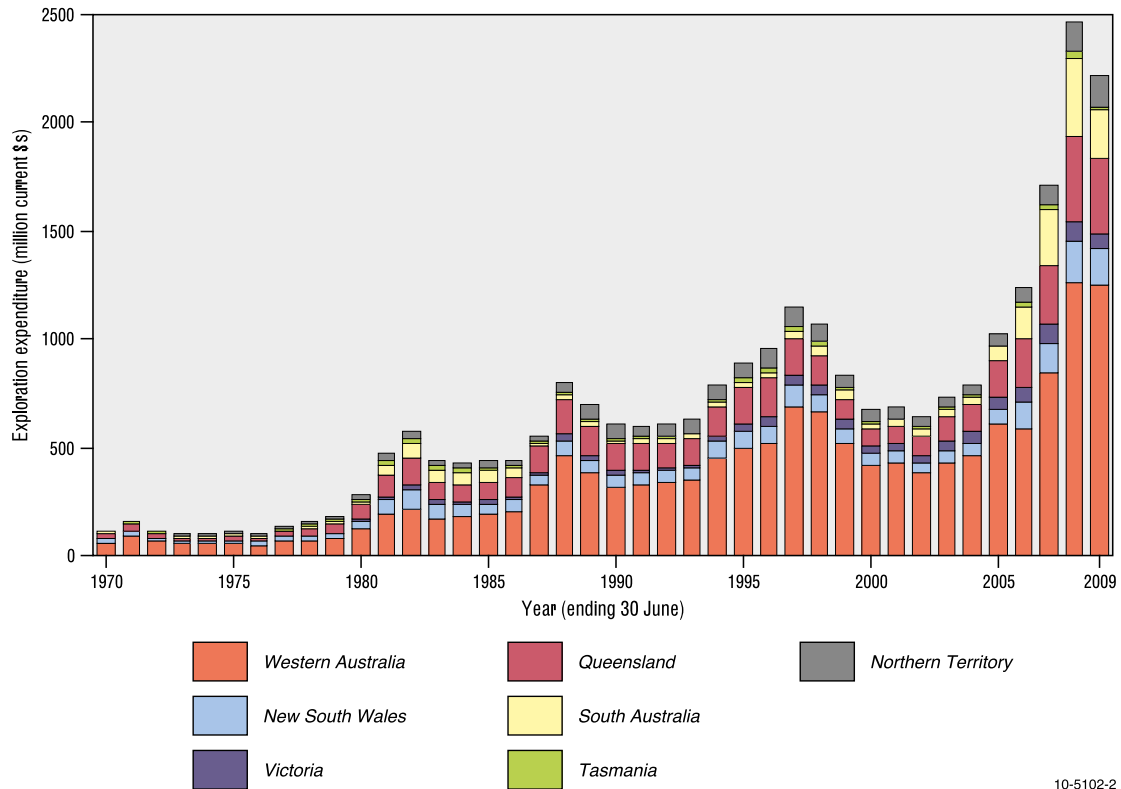
On the back of record spending iron ore became the major commodity targeted, accounting for 26% of total exploration spending. Total iron ore spending in 2008–09 rose by 31% from 2007–08 to a record \$588.7 million (Fig. 4). In contrast the base metals and gold recorded substantial falls in spending. Although base metals as a group remained the second largest exploration target, exploration spending fell by 34% to \$519.0 million with significant reductions recorded for the three component commodities—copper down by 39% to \$178.7 million, zinc, lead, silver down by 57% to \$80.5 million and nickel cobalt down by 14% to \$259.8 million. Gold exploration spending fell by 35% to \$438.1 million. Coal, like iron ore achieved record exploration spending in 2008–09 of \$297.3 million an increase of 27%.

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



Spending fell in all jurisdictions except the NT where an increase of 10% to \$146.1 million (Fig. 5) was recorded as spending rose for uranium, iron ore and other commodities such as manganese, phosphate and rare earth elements. South Australia (SA), Tasmania (Tas) and Victoria (Vic) suffered the largest proportional falls in spending of 37.9%, 37.0% and 33.0% respectively. Smaller falls were recorded in Queensland (down 11.6%), New South Wales (NSW) (down 7.7%) and WA where the decline was only 1%.

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



Exploration Stage

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

ABS survey data on spending showed that nationally 37.8% of spending was on exploration for new deposits, compared to 41.1% in 2007–08. Tas, with 58.3%, had the highest proportion of its exploration directed to the search for new deposits while Queensland had the lowest at 29.2%. The national share of exploration for new deposits is almost the same as the Metals Economics Group (MEG) world survey of non-ferrous minerals exploration budgets for 2009 which found that 37.4% of those budgets in Australia was for grassroots exploration.

Exploration Drilling

In 2008–09, ABS reported that exploration drilling totalled 7.888 million metres, a reduction of 1.868 million metres from 2007–08. Drilling in the search for both new deposits and on existing deposits suffered significant falls in 2008–09. A reduction of 1.2 million metres occurred in drilling in search of new mineralisation with a total of 2.72 million metres drilled. Drilling on existing deposits fell by 0.669 million metres to a total of 5.167 million metres.

In 2009 some 30 initial public offerings on the Australian Securities Exchange were fully or partially for mineral exploration in Australia. This was a substantial reduction on the 48 listings in 2008.

Calendar Year 2009

On a calendar year basis, exploration spending in 2009 fell by 22% to \$2023 million as the results of reduced demand for commodities caused by the world economic crisis.

While the reduction in exploration spending in 2009 was substantial at 22%, it was a year of two halves with substantial reductions in the March and June quarters being moderated by lower reductions in the September and December quarters. The falls in the March and June quarters were 25.8% and 33.6% respectively. However, in the September and December quarters the rate of reduction slowed considerably with falls of 19.0% and 10.7% respectively. This slowing suggests that the impact of the global financial crisis was moderating by the end of 2009.

In 2009, iron ore maintained its position as the predominant commodity explored for in Australia. Although down, spending on iron ore exploration accounted for 25.6% (\$21 million) of total exploration spending while gold's share was 22.9% (\$463.3 million). As a group the base metals suffered a major reduction in exploration with total spending falling by 51% to \$369.3 million, making the group the third largest target. Spending on the individual commodities in the base metals group in 2009 was: copper \$134.8 million less than half the 2008 level; lead-zinc-silver \$48.2 million, only 36% of the 2008 level and nickel-cobalt \$186.3 million, which was just above half of the 2008 level.

Uranium exploration spending in 2009 fell to \$179.6 million compared to \$220.5 million in 2008. In contrast to all other commodities reported by ABS coal exploration rose in 2009 with growth of 13% to \$312.7 million which reflected continuing strong demand for coal from Asia despite the global financial crisis.

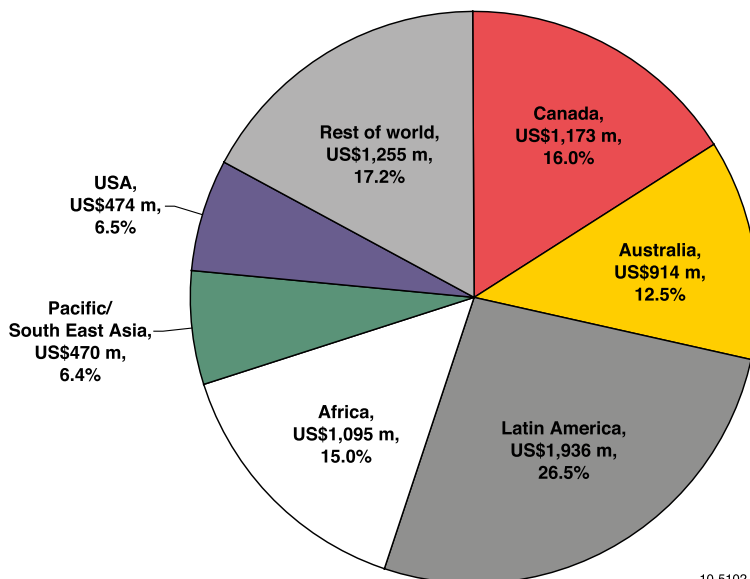
The NT was the only jurisdiction to record increased exploration spending in 2009 albeit a modest 0.8% increase to \$148.4 million. Of the States, Tas and SA suffered the largest percentage falls with reductions of 54.9% and 48.7% respectively. WA remained dominant with a small increase to 55.3% of Australian spending despite a reduction of in total spending in the State to \$1119.6 million.

Exploration Outcomes

The ongoing strong exploration activity saw a very large number of intersections of economic grade and several new discoveries reported. A major review of the highlights of mineral exploration in Australia in 2009 is available in the document *"Australian Mineral Exploration: A Review of Exploration for the Year 2009—Extended Edition"* available for download from the Geoscience Australia web site.

Responding to world demand there was substantial activity in the iron ore and coal sectors with new resources and drilling results released for many smaller deposits and prospects.

Figure 6. Distribution of world non-ferrous mineral exploration budgets (excluding uranium) as reported by companies, 2009 (Source: Metals Economics Group).



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World Exploration

The MEG survey of world non-ferrous mineral exploration budgets for 2009 reported a substantial fall of 42% in non-ferrous mineral exploration budgets to US\$7.7 billion. MEG included uranium in the survey for the first time in 2007 and it estimated that with uranium included world budgets for non-ferrous mineral exploration in 2009 was US\$8.4 billion. Of that total, US\$1088.8 million was targeted at exploration in Australia. Excluding uranium, Australia's share of global non-ferrous mineral exploration budgets fell from 13.6% in 2008 to 12.5% in 2009 although it remained the country with the second highest share of budgets after Canada with 16% (Fig. 6).

According to the MEG survey, 47% of the 2009 non-ferrous mineral exploration budget for Australian-based companies was for exploration in Australia. This was a significant reduction from the 56% recorded in 2008 and was the lowest level recorded in the past decade. The survey included 490 companies with non-ferrous exploration budgets of more than US\$100 000 which were exploring in Australia compared to 519 in 2008. Budgets for Australian non-ferrous mineral exploration included: gold (US\$445.5 million) and base metals (US\$366.0 million). World uranium exploration budgets in 2009 totalled US\$664 million, a reduction of 42% from 2008, of which Australia received 26% making it the second largest after Canada which received 29%.

Outlook for Exploration

Both world and domestic mineral exploration levels fell substantially in 2009 as the impact of the global financial crisis was felt. Australian exploration was subject to the same pressure but with iron ore and coal being significant components in its exploration spectrum Australia was not as badly impacted as other countries. However, with the gradual improvement in the world economic situation and the continued strong demand for bulk commodities from Asia the outlook for mineral exploration in Australia is good. If the continued high price of gold is maintained or increased further, investment in gold exploration should add further impetus to exploration as a whole.

After a difficult period which was moderated in Australia by the continued growth in China mineral exploration is likely to resume growth in 2010.

Offshore Mineral Exploration in Commonwealth Waters

Ron Sait (contact aden.mckay@ga.gov.au)

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, the States and the Northern Territory. The Joint Authority consists of the relevant Commonwealth Minister and the State and Northern Territory Ministers and is responsible for major decisions such as grants and refusals. The relevant State and Northern Territory Minister is called the Designated Authority and is responsible for the administration of the Act. Applications for a mineral exploration licence (MEL) are made to the Designated Authority.

As at June 2010, a total of about 95 offshore MEL applications had been received since February 1990.

Two licences, T-2-MRL and T-3-MEL in Ringarooma Bay in northeast Tas, were surrendered in December 2009. In July 2009 MIG Resources Pty Ltd applied for four Offshore Mineral Exploration Licences in the Joseph Bonaparte Gulf of WA. In June 2010, Groote Resources Ltd applied for nine Offshore Mineral Exploration Licences south of Groote Eylandt in the NT.

An Australian Offshore Minerals Locations Map which shows 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. The Australian Offshore Mineral Locations data 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

ABARES Australian Bureau of Agricultural and Resource Economics and Sciences

ABS Australian Bureau of Statistics

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

AEDR Accessible Economic Demonstrated Resources

BRS Bureau of Resource Sciences

c carat

CBM coal bed methane

CMM coal mine methane

CSG coal seam gas

cpht carats per hundred tonnes

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

LNG liquefied natural gas

m metre

Mc million carats

MEL mineral exploration licence

ML million litres

Mozs million ounces

Mt million tonnes

Mtpa million tonnes per annum

MW megawatt

MWe megawatt electric

NSW New South Wales

NT Northern Territory

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

ozs ounces

PDR Paramarginal Demonstrated Resources

PGE platinum-group elements

PJ petajoules

ppm parts per million

Qld Queensland

RAR Reasonably Assured Resources

REO rare earth oxide

REE rare earth element

SA South Australia

SDR Subeconomic Demonstrated Resources

Tas Tasmania

tpa tonnes per annum

U uranium

U₃O₈ uranium oxide

USA United States of America

USGS United States Geological Survey

US\$ United States of America dollar

Vic Victoria

WA Western Australia

\$1M million dollars

Appendix 2

Australia's 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.

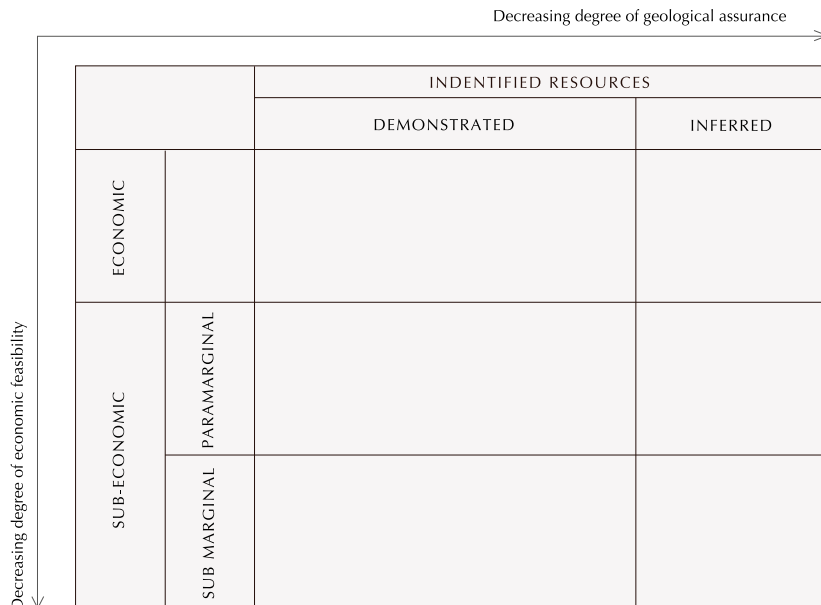
In 1975, Australia (through the Bureau of Mineral Resources, which has evolved to become Geoscience Australia) adopted with minor changes the McKelvey resource classification system used in the USA by the then Bureau of Mines and the United States Geological Survey (USGS). Australia's national system 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 Measured Resources and Indicated Resources and Reserves.
- New discoveries will add to the resource inventory.

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



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.

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:

'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.

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.

'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.

'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?

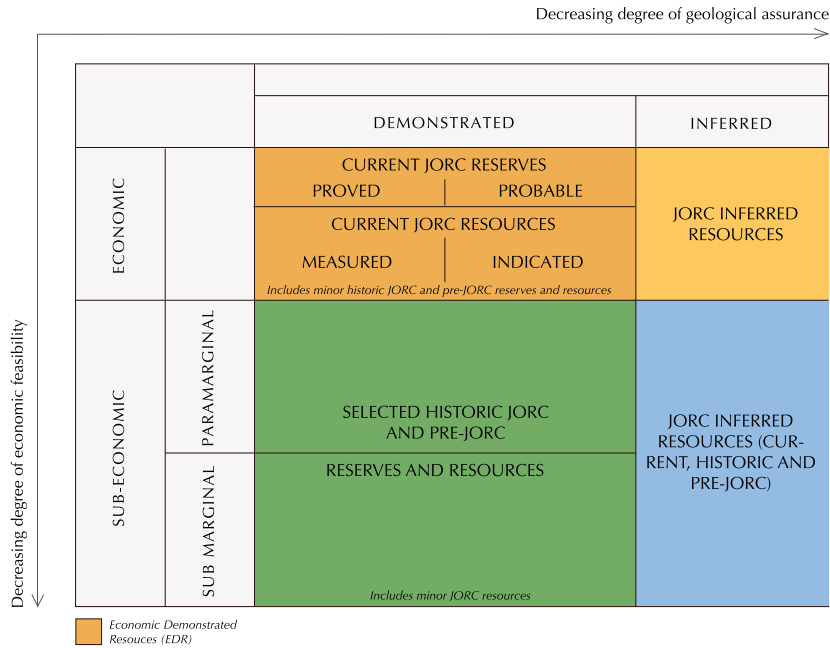
Virtually all of the mineral resource estimates compiled by Geoscience Australia's commodity specialists, including Subeconomic Resources, originate from published mining company sources reporting under the JORC Code. Given the common resource categories and definitions, the transfer of mineral resources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

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.

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



Notes:

- 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 proportions of resources from current company reports which are JORC Code compliant but have been assessed by Geoscience Australia as subeconomic.

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

Mineral Resources and Advice Project

Name	Telephone	Email	Commodity
Leesa Carson (Group Leader)	+ 61 2 6249 9872	leesa.carson@ga.gov.au	Shale oil, tantalum, niobium, phosphate
Aden McKay (Project Leader)	+ 61 2 6249 9230	aden.mckay@ga.gov.au	Uranium, tin, tungsten
Mike Huleatt	+ 61 2 6249 9087	mike.huleatt@ga.gov.au alan.whitaker@ga.gov.au	Gold, exploration expenditure
Yanis Mieзитis	+ 61 2 6249 9523	yanis.mieзитis@ga.gov.au	Nickel, cobalt, PGE, mineral sands, rare earths, thorium
Keith Porritt	+ 61 2 6249 9479	keith.porritt@ga.gov.au	Copper, zinc, lead, silver, diamond
Ron Sait	+ 61 2 6249 9230	aden.mckay@ga.gov.au	Coal, coal seam gas, coal to liquids, iron ore, offshore mineral exploration
Paul Kay	+ 61 2 6249 5829	paul.kay@ga.gov.au	Bauxite-alumina-aluminium
Alan Whitaker	+ 61 2 6249 9702	alan.whitaker@ga.gov.au	Gold, vanadium
Roy Towner	+61 2 6249 9874	roy.towner@ga.gov.au aden.mckay@ga.gov.au	Lithium, magnesite, molybdenum, tantalum, niobium, tin tungsten.
Michael Sexton	+ 61 2 6249 9672	michael.sexton@ga.gov.au	Manganese ore, Information management and project data support

Postal Address

Geoscience Australia
GPO Box 378
Canberra ACT 2601
AUSTRALIA

Location

Cnr Jerrabomberra Ave and Hindmarsh Drive
Symonston ACT 2600
AUSTRALIA

Internet

www.ga.gov.au/minerals

ABN

80 091 799 039

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